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A Field Guide To

The Illinois Caverns State Natural Area: Teacher's Curriculum

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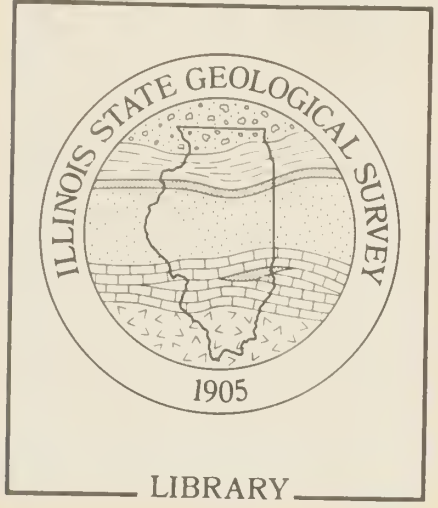
Samuel V. Panno, Sallie E. Greenberg,
C. Pius Weibel, and Patricia K. Gillespie

GeoScience Education Series 2002

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY



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Samuel V. Panno, Sallie E. Greenberg,
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GeoScience Education Series 2002

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Table Of Contents

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Introduction 5

Field Trip Preparation 6

Suggested Field Trip Preparation 6

Information Sheets 10

Karst and the Formation of Illinois Caverns 10
The Hydrologic Cycle in Karst Terrain 16
The Cave Stream 23
Cave Deposits of Illinois Caverns 25
The Directional Trend and Cross-Sectional Shape of Cave Passages 31

Classroom Activities 32

Create a Karst Terrain Map 32
Create a Sinkhole Density Map 37

Field Activities 46

Geologic Mysteries of Illinois Caverns 46
The Scientific Process and Alternate Interpretations 46
Mystery 1: The Entrance 47
Mystery 2: Human Visitation 51
Mystery 3: Age of Stalactites 55
Mystery 4: How Chimneys and Speleothems Form in the Same Environment 59
Mystery 5: Tilted Speleothem 65
Mystery 6: Mushroom Passage 70
Mystery 7: Capitol Dome 76

Acknowledgments 82

Introduction

This is a supplement to "A field guide to the Illinois Caverns State Natural Area" and was written for students from about 5th grade through high school. This document is intended to give teachers a variety of activities for students before, during and after their field trip to Illinois Caverns. This is a companion document that may be used to provide lessons which will acquaint students with the geological, hydrological, chemical and biochemical processes that form karst regions and caves. The lessons include student assignments and instructions for the educator with explanations, material lists, and suggestions for discussion. For the student, lessons offer easy-to-follow instructions and data sheets for recording observations and discoveries. Each lesson provides an experiential activity and thought-provoking questions. Certain activities may be used as an introduction before cave exploration and/or as reinforcement after a visit to Illinois Caverns State Natural Area. Some of the lessons may be used successfully without a cave visit. The lessons are designed to allow students to become scientists themselves, drawing inferences from observations, solving problems through critical thinking, and communicating their ideas effectively.

Illinois Learning Standards Matrix

Activity Number and Title	11A	11B	12A	12B	12C	12D	12E	12F	13A	13B
Classroom Activities										
Sugar Cave	X						X		X	X
Karst Mapping and Sink Hole Density	X	X					X		X	X
Land-Use Planning in Karst Terrain	X	X					X		X	X
Field Activities - Geological Mysteries										
The Entrance	X						X		X	X
Ages of Stalactites	X						X		X	X
Human Visitation	X						X		X	X
Chimneys and Stalactites	X						X		X	X
Tilted Speleothems	X						X		X	X
Mushroom Passage	X						X		X	X
Capitol Dome	X						X		X	X

X = Emphasis in Content

National Science Education Standards Matrix

Please see the key to the content standards at the bottom of this page.

Activity Number and Title	Suggested Grade Level		Content Standards						
	5-8	9-12	A	B	C	D	E	F	G
Classroom Activities									
Sugar Cave	X		X	X		X			X
Karst Mapping and Sink Hole Density	X	Y	X, Y	X, Y		X, Y		X, Y	X, Y
Land-Use Planning in Karst Terrain	X	Y	X, Y	X, Y		X, Y		X, Y	X, Y
Field Activities - Geological Mysteries									
The Entrance	X	Y	X, Y	X		X, Y		X	X, Y
Ages of Stalactites	X	Y	X, Y	X		X, Y		X	X, Y
Human Visitation	X	Y	X, Y	X		X, Y		X	X, Y
Chimneys and Stalactites	X	Y	X, Y	X		X, Y		X	X, Y
Tilted Speleothems	X	Y	X, Y	X		X, Y		X	X, Y
Mushroom Passage	X	Y	X, Y	X		X, Y		X	X, Y
Capitol Dome	X	Y	X, Y	X		X, Y		X	X, Y

A = Science as Inquiry B = Physical Science C = Life Science D = Earth and Space Science
E = Science and Technology F = Science in Personal and Social Perspectives G = History and Nature of Science
X = Emphasis in Content for 5-8 Y = Emphasis in Content for 9-12

FIELD TRIP PREPARATION

Suggested Field Trip Preparation

Safety Rules

A field trip to Illinois Caverns is a wonderful adventure. However, there are many safety rules and regulations that you must follow when you visit the cave.

Because Illinois Caverns is a substantially wild, unimproved cave system, visitors must use adequate safety equipment, including hard hats, two dependable sources of light, leather boots, and suitable protective clothing. Visitors should plan on getting their feet wet and muddy.

Walking inside the cave is relatively easy, but it is slick in many places, there is some climbing (assisted by ladders and steps), and some places where the cave narrows to less than 3 feet wide. Persons visiting the cave should realistically consider any physical limitations that might cause discomfort in the cave.

All persons visiting the cave should use bathroom facilities at the surface. There are no bathrooms in the cave.

Safety Issues:

1. Bring two good, relatively large flashlights for each person. Have extra batteries.

2. The steps leading into the cave are very steep and can be slippery.

3. Like surface streams in the area, the cave stream water has high levels of bacteria. Do not drink the water and avoid contact with open wounds. If eating snacks in the cave, avoid handling food directly with soiled hands. Upon returning to the surface, wash your hands, especially before eating. We suggest you bring an anti-bacterial packaged hand wipes to cleanse hands or to cleanse minor wounds that might have come in contact with water or mud within the cave.

4. Footing throughout the cave can be slippery. Proceed with caution.

5. Hardhats must be worn at all times. It is easy to bang your head on overhanging rocks.

6. Long pants and long-sleeved shirts should be worn to avoid abrasions.

7. Do not climb on rocks and cave formations.

8. If you get lost or separated from the group:
   a. Stay in one place and periodically call out for help.
   b. Keep dry and stay out of the stream.

9. Bring a first-aid kit.

10. If someone is injured to the point where they cannot walk or climb safely, have one person stay with the injured person and send 2 other people for help immediately. Keep the injured person as warm, dry, and comfortable as possible, and follow standard first-aid practices.

Pre-Trip Preparation

Contact Illinois Caverns for hours of operation. Make reservations with the Site Interpreter to ensure access to the cave, especially for groups over 25.

Read Illinois Caverns Field Guide and share with students

Conduct pre-trip activities

Plan field trip with students (select driving route to see karst features)

Arrange transportation

Arrange chaperones for students (approximately 1 adult per 3 or 4 students is recommended)

Prepare directions for drivers

Arrange for lunches, snacks, drinking water, hand-washing water and soap, change of clothing.

There are restroom and changing facilities on site.

Provide students with a checklist of items to take on field trip. These should include:

Hardhat
Two sources of light and extra batteries
Craggy-soled boots (running and tennis shoes are too slick)
Long pants (jeans work well)
Long-sleeved shirt (the air temperature in the cave is about 60 degrees F all year)
Optional items include: Towel, change of clothes and shoes, bag for wet clothes, camera and extra film, small notebook and pen, magnifying glass or hand lens, small ruler. A daypack or small backpack is help ful for carrying extra materials (like snacks and water) and keeps the students hands free.

Teacher prepares materials to bring on fieldtrip:

Handouts
Activity materials
Maps of the sinkhole plain and route to Illinois Caverns
Maps of the cave and surrounding karst area

Describe the fragile nature of the Illinois Caverns State Natural Area and the expected behavior of the students during their visit.

Describe the activities that the students will perform at the natural area and in the cave.

Restricted Access Within Illinois Caverns

At this writing, not all areas within the cave at the Illinois Caverns State Natural Area are owned by the state. Please consult the site interpreter as to the current location of the state boundaries; property boundaries may be subject to change with the acquisition of land by the state. If your party wishes to go beyond the designated state-owned property without trespassing on private property, it will be necessary to get permission from the property owners. The site interpreter can give you information as to how to contact the land owners.

Day Before the Trip

Check the weather. Several weather-related conditions may cause the cave to be temporarily closed. They include severe rainstorms with the potential for flash floods underground, and large snowfalls and/or ice buildups on the stairs leading into the cave, both of which can make access hazardous. Call the Site Interpreter at Illinois Caverns to finalize the arrangements.

Review safety procedures.

Pack all field trip materials and equipment.

Day of the Field Trip

Give the driver directions to the sinkhole plain, Illinois Caverns, and any additional stops.

The following are descriptions of the area approaching Illinois Caverns from several directions to discuss with students as you near Illinois Caverns:

The most easily seen karst features in this area are nearly circular depressions formed in the wind-deposited silt (loess) and glacial drift that overlies the heavily creviced St. Louis Limestone. Most caves in this area were formed in the St. Louis Limestone.

From the NORTHEAST (Rte. 158): Starting at Rodemich, the route travels through about 2 miles of karst terrain. Sinkholes occur on both sides of the highway until about ½ mile before the intersection of

Routes 3 and 158. Follow the below approach route from the North.

From the NORTH (Rte. 3): The first view of karst features will be in the road cuts at the intersection of routes 3 and 158, just southeast of Columbia. At the upper end (southwest) the road cut exposes the Salem Limestone. The soil-mantled limestone contains sinkholes and dissolution features at the top of the bedrock. At about 1 mile south of the intersection, there are sinkholes to the west of the route for about 1/4 mile. After an additional 2 miles, about midway between Columbia and Waterloo, a significant number of sinkholes occur to the east of Route 3. This sinkhole area continues for about 2 miles.

Starting at about 1 mile south of Waterloo, sinkholes occur first on the east side of the highway for 1 mile, and then on both sides of the highway for an additional mile. See below for the route description of karst features from Route 3 to Illinois Caverns.

From the SOUTH (Rte. 3): Between Ellis Grove and Evansville, just southeast of the Kaskaskia River, Route 3 traverses through two large sinkhole areas. Sinkholes occur on both sides of the highway. See below for the route description of karst features from Rte. 3 to Illinois Caverns.

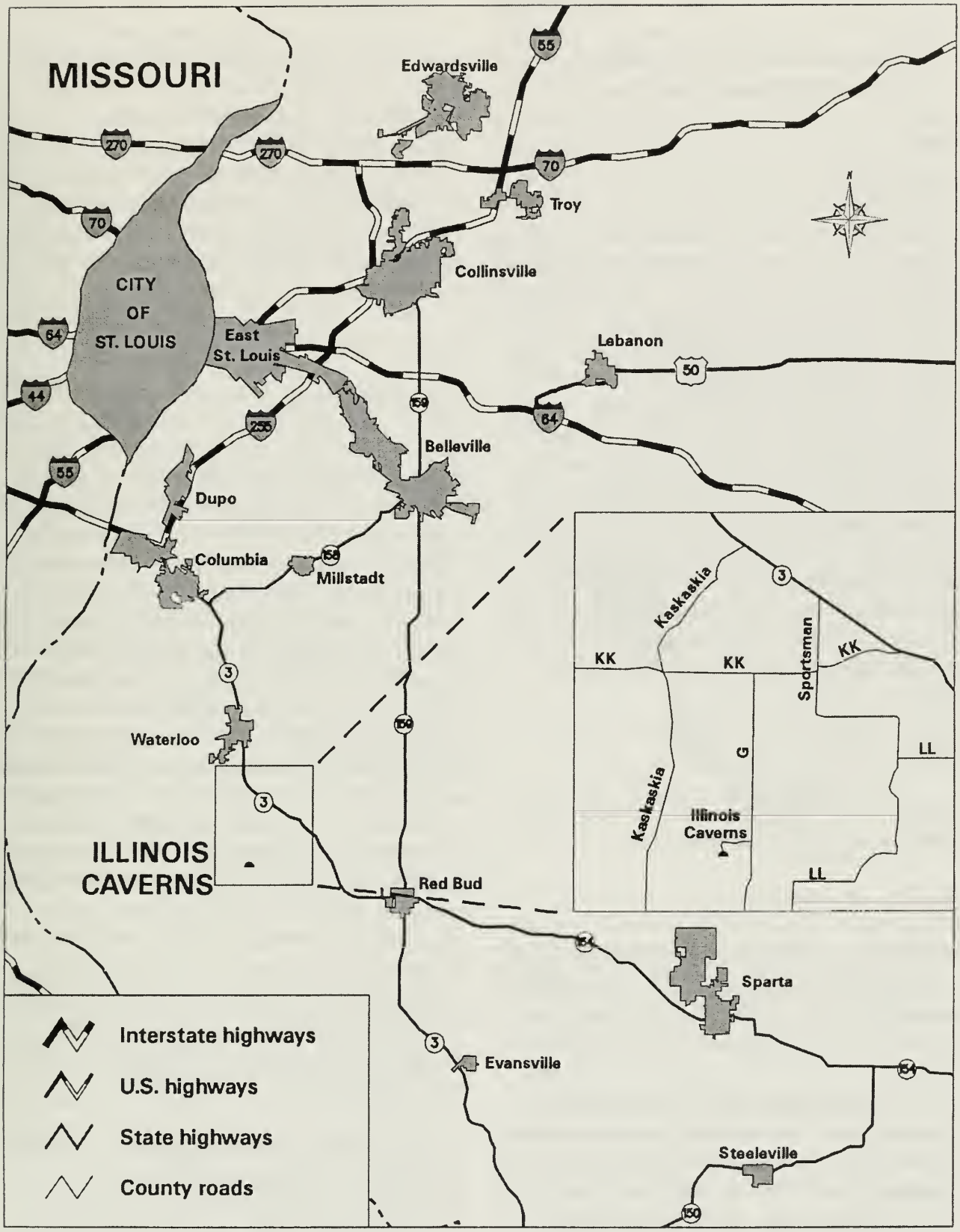
From Route 3 to Illinois Caverns: After traveling one mile from Route 3 on Kaskaskia Rd., the route traverses through a sinkhole area into the village of Burksville. Turning to the east onto KK Rd. within Burksville, sinkholes occur along the road for about another ½ mile. After turning south onto G Rd. and traveling about 3/4 miles, the route enters the sinkhole area surrounding Illinois Caverns. The turn-off to Illinois Caverns is about one more mile to the south.

Final Preparations

Distribute safety and field equipment and materials.

Discuss safety procedures in the karst area and before entering cave. Specifically, the steep walls at the bottom of the sinkhole leading to Illinois Caverns are a good example of potentially steep drops in the area. Climbing within the cave is especially dangerous because of the slippery nature of the cave walls and the abundance of large angular rocks. In addition, a slow and steady progression through the cave is suggested because of the potential for slipping and falling off steep slopes, ledges, bridges, and ladders.

Instruct students to use restroom facilities before entering the cave. There are no facilities in the cave.



Location map of southwestern Illinois and eastern Missouri, and a detail of roads leading to Illinois Caverns and the Illinois Caverns State Natural Area.

Karst And The Formation Of Illinois Caverns

Karst

What Is Karst?

Karst is a distinctive landscape in which the landforms are primarily shaped by the dissolving action of water on limestone (or other carbonate) bedrock and associated collapsing soil (Figures 1 and 2). The drainage of rainwater and snowmelt through underground conduits and crevices (vs. surface streams) is the norm. Sinkholes, caves, and large springs typically characterize karst terrain. The geological process of karst formation begins with snow and rain falling upon soil-covered or exposed limestone bedrock. Rain falling through the atmosphere picks up carbon dioxide, which is dissolved into the raindrops. As the rainwater and snowmelt flow down through the soil, the water becomes further enriched with carbon dioxide, forming a weak solution of carbonic acid:

$$H_2O + CO_2 \leftrightarrow H_2CO_3.$$

The carbonic acid dissociates, in water, into a hydrogen ion and a bicarbonate ion:

$$H_2CO_3 \quad H^+ + HCO^{3-}.$$

Dissolving CO_2 in the water slightly increases the normal dissociation of H_2O to form the ionic species $H^+ + [CO_2\,(OH)]^-$. The increased concentration of hydrogen ions is reflected by a decrease in the pH of the solution. The slightly acidic water continues to flow down into the limestone bedrock, commonly through pre-existing fractures and along bedding planes. Tiny amounts of the mineral calcite (limestone is mostly calcite) are dissolved by carbonic acid:

$$CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO^{3-},$$

until, after several days of interaction with bedrock, the acid is neutralized. Over long periods of time (thousands to hundreds of thousands of years) and with a continuous supply of carbon dioxide-enriched water, limestone bedrock slowly dissolves along fractures and bedding planes to form a more open and more permeable system that becomes a karst aquifer. Caves and large springs are typical of a fairly mature karst aquifer system (Figure 3).

What Are Sinkholes?

The most obvious karst landform is the sinkhole, a topographic depression in the thick soil that overlies the bedrock of the sinkhole plain (Figure 4). These circular to elliptical features form as the dissolution of bedrock enlarges crevices and cavities in the bedrock below the soil cover. As the crevices within the bedrock enlarge, the soil can collapse into the crevices (from the bottom, up) and be carried away by flowing groundwater. A hemispherical or silo-shaped cavity forms underground (in the soil) as the cavity works its way to the surface over the course of hours, days, or months. When the cavity approaches the surface, the surface materials fall into the cavity creating a sinkhole that appears, from the perspective of the viewer on the surface, to have formed instantly. The initial sinkhole has nearly vertical sides that are rapidly eroded by rainfall and drainage, into a bowl-shaped depression that acts as a small basin for funneling surface water into the karst aquifer. Newly formed sinkholes are extremely dangerous due to the instability of their walls. The unwary explorer of such a new feature can be buried beneath tons of soil in seconds.

Karst windows are special types of sinkholes that result from the total collapse, up to the land surface, of the roof of a cave. Karst windows ("windows to the underground") are a relatively rare feature in the sinkhole plain. Sinking streams occur in karst landscapes where some or all of the flow of a surface stream is diverted into the subsurface drainage system. A swallow hole

(or swallet) refers to the pit or opening where a sinking stream dives underground. The downstream or distal end of such a drainage system is a topographically lower area where the water that entered the sinkhole discharges to the surface at a spring or resurgence. Karst springs characteristically have flow rates that increase rapidly with the onset of a precipitation event and decrease shortly after the precipitation has stopped. They are referred to as "flashy" because they can cause flash floods in an otherwise dry streambed, as well as within a cave system.

Caves

What Is A Cave?

A "cave" is defined as a naturally occurring cavity in rock that is large enough for a person to enter and travel far enough from the entrance to experience total darkness. Caves are an important part of the karst hydrologic cycle; they provide subsurface pathways that drain the land of rainfall and snowmelt. In spite of their large size, caves may comprise only a small part of the total conduit system of a karst aquifer. The water in a cave, correctly referred to as groundwater, flows to and eventually through the cave system until it is discharged (returns to the surface) at a resurgence (rise or spring) in a low-lying area (e.g., a river valley). The water then enters surface streams where it flows to lakes and seas.

How And When Did Illinois Caverns Form?

The formation of Illinois Caverns began when the Mississippian-age limestone (rock that was formed from the deposition of lime muds and shells at the bottom of a sea 340 to 300 million years ago) was exposed at or near the surface in southwestern Illinois due to movement of the earth's crust. The bedrock of the sinkhole plain was tilted slightly upward when the statewide, spoon-shaped depression, known as the Illinois Basin was formed. Most of that movement is thought to have occurred between about 300 million years and 250 million years ago. Southwestern Illinois is on the western flank of the Illinois Basin. This depression in the crust and subsequent erosion of overlying rock brought the limestone to the surface in southwestern Illinois. In the course of this and subsequent movements, the bedrock in this area was fractured and bedding planes of the limestone were slightly separated (dilated). The fracturing of bedrock and dilation of bedding planes set up the soluble limestone bedrock for a focused attack by infiltrating surface water.

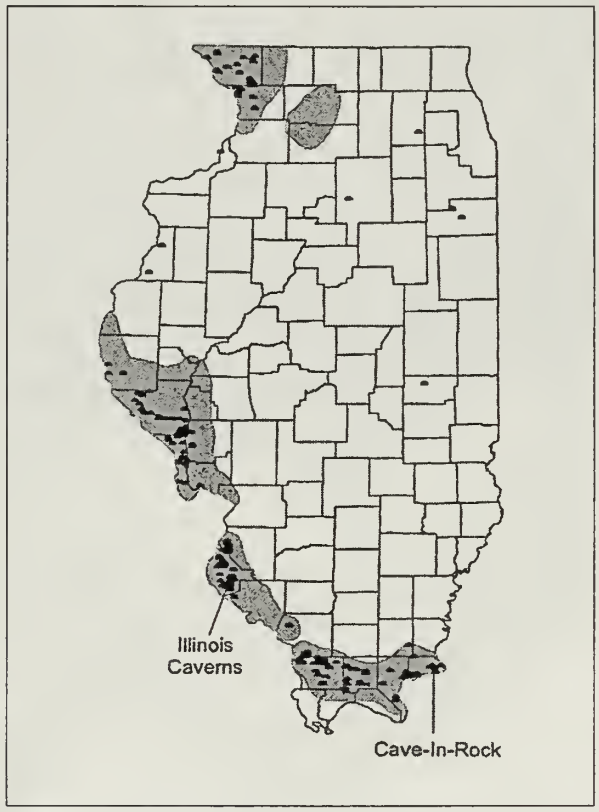


Figure 1. *This map of the karst regions of Illinois (gray) shows the approximate locations of more than 300 caves in Illinois. The locations of the two best known caves in the state are indicated. The karst terrain was mapped on the basis of numerous sinkholes that characterize karst landscapes.*

Following the fracturing of the bedrock, slightly acidic rainfall, snowmelt, and somewhat more acidic soil water began to infiltrate into the tight, vertical fractures and the connected horizontal and dilated bedding planes, and slowly dissolve the limestone. Over tens to hundreds of thousands of years, the flow of acidic water along fractures and bedding planes dissolved the bedrock and led to the formation of near vertical

Figure 2. *A block diagram of the karst terrain of the sinkhole plain showing bedrock and the relationship between crevices and sinkholes. Notice that the bedrock dissolves along bedding planes forming horizontal opening that can extend, as conduits, for miles. If accessible, these conduits are referred to as caves.*

crevices (up to several inches wide) and small conduits along bedding planes (up to 3 or 4 inches in diameter) known as anastamoses (Figures 5 and 6).

Recent work by the ISGS suggests that the largest caves of the sinkhole plain began to form when glacial ice from the Illinois Glacial Episode began to melt and the ice that covered much of Illinois during the episode began to recede to the north. The glacier was about 500 feet thick in this area and provided a lot of ice water as it melted. Cold water can hold more CO_2 in solution and therefore it dissolves limestone faster than warm water. As a result, Illinois Caverns and other caves in the area began to form as the glaciers above their locations began to melt (about 125,000 years ago).

Groundwater flowed downward through the crevices, and then laterally along bedding plane partings that eventually became horizontal con-

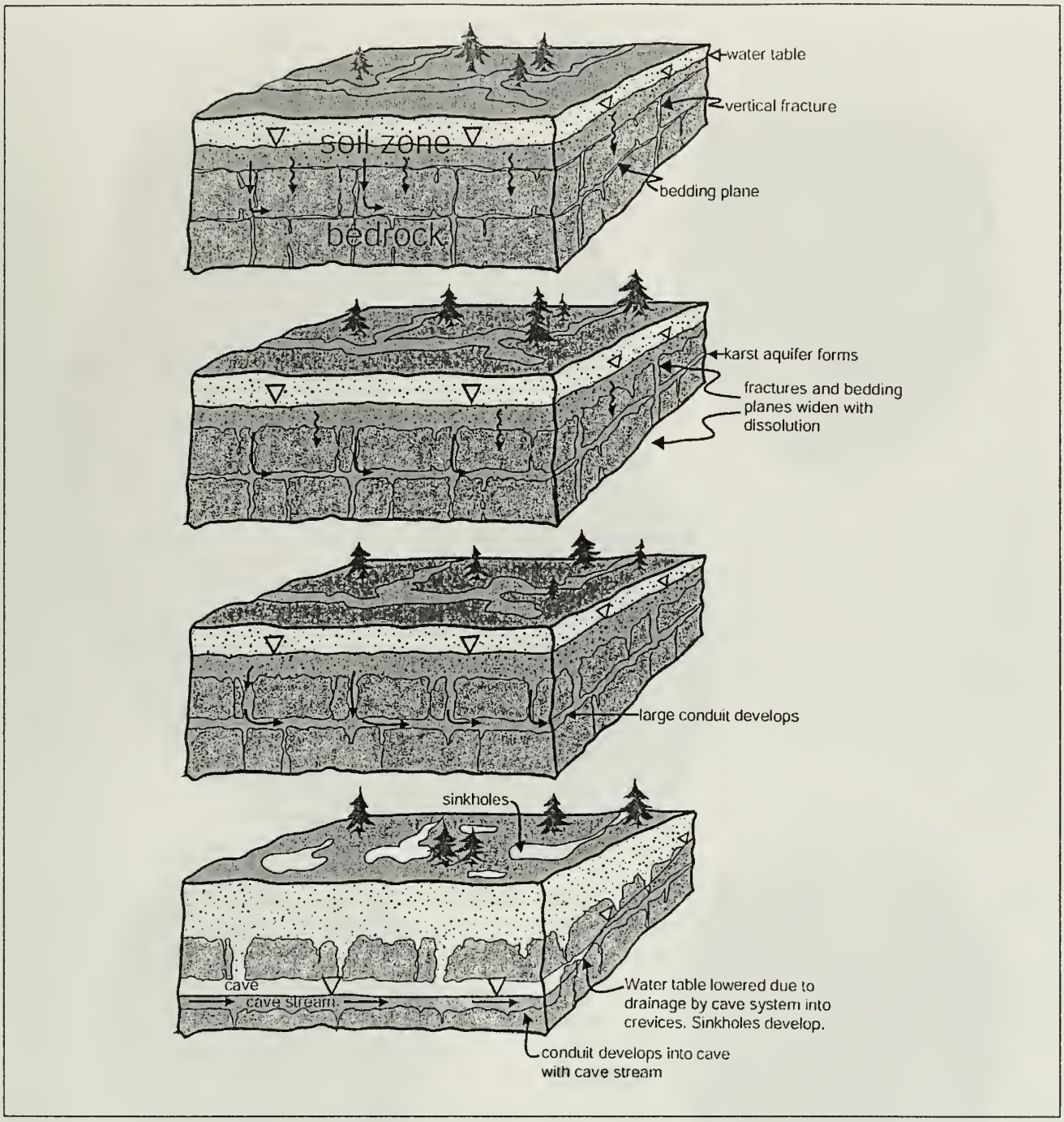


Figure 3. *The development of karst terrain (sinkholes and caves) depends on the position of the water table and the enlargement of crevices and bedding planes. Slightly acidic rainfall and snow melt enter the soil and become more acidic. As they flow through the crevices and along bedding planes, they enlarge them. The larger openings allow more water to flow through them, thereby increasing their rate of enlargement. If one of the conduits begins to enlarge faster than nearby conduits (for example, in a low lying area), then the nearby groundwater will begin to flow toward the larger conduit. This, in turn, causes the conduit to enlarge at an even faster rate. When large enough, the conduit becomes dominant and begins to drain the groundwater so fast that the water table drops to a level within the cave. When the water table drops below the contact between the soil and the bedrock surface, sinkholes can form and surface streams can flow into them or simply disappear. At that point, the flow of water in the area is now underground.*

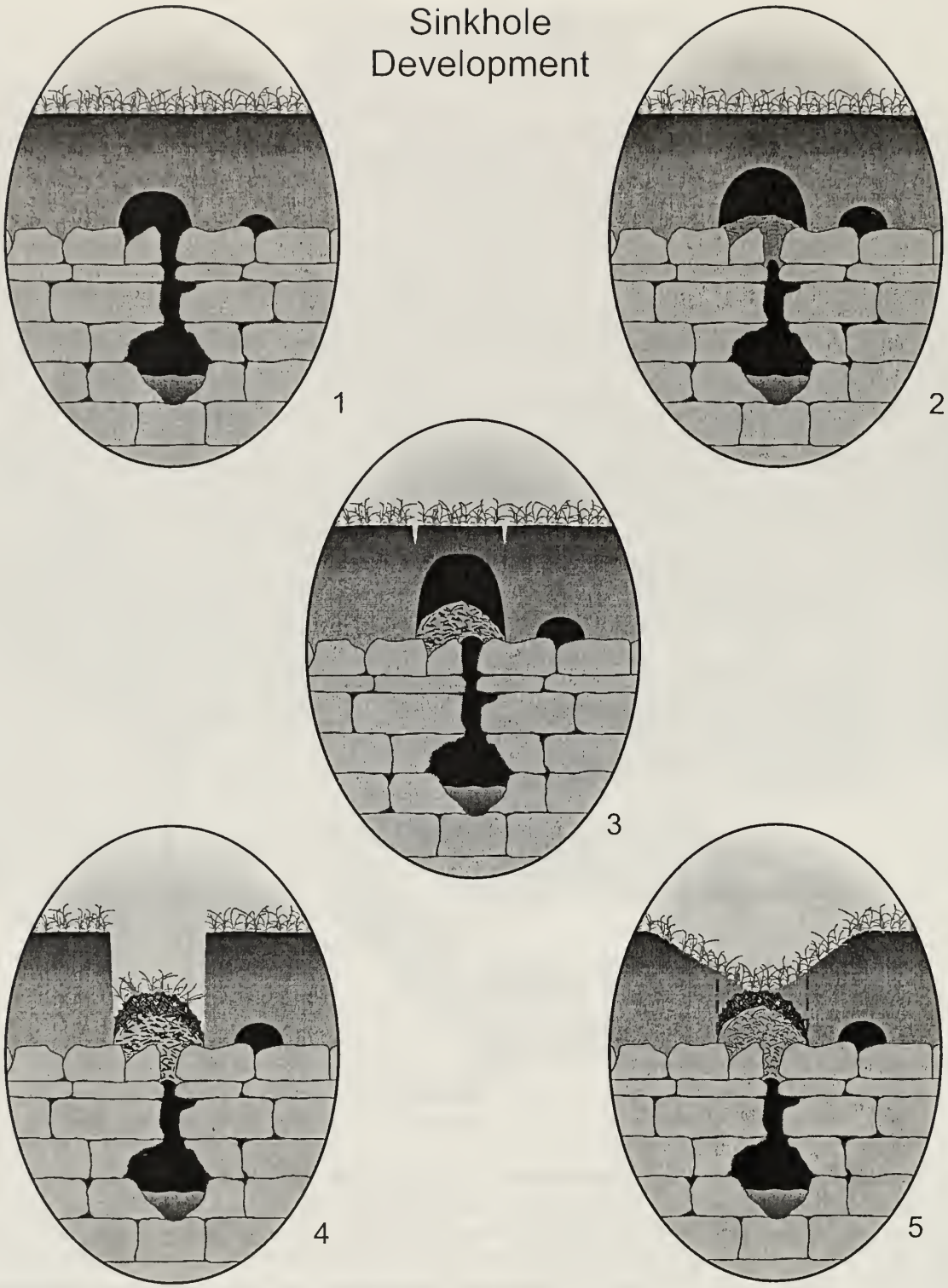


Figure 4. The formation of a sinkhole is shown in this sequence of events. Initially, soil collapses into a crevice (1) and is carried away by water flowing through conduits. Additional collapse occurs (2) until circular cracks develop at the surface (3). At that point, the soil cap falls into the developing cavity and a cylindrical hole is formed (4). Erosion by water flowing into the hole during rainfall and snowmelt converts the hole into a cone- or bowl-shaped depression (5).

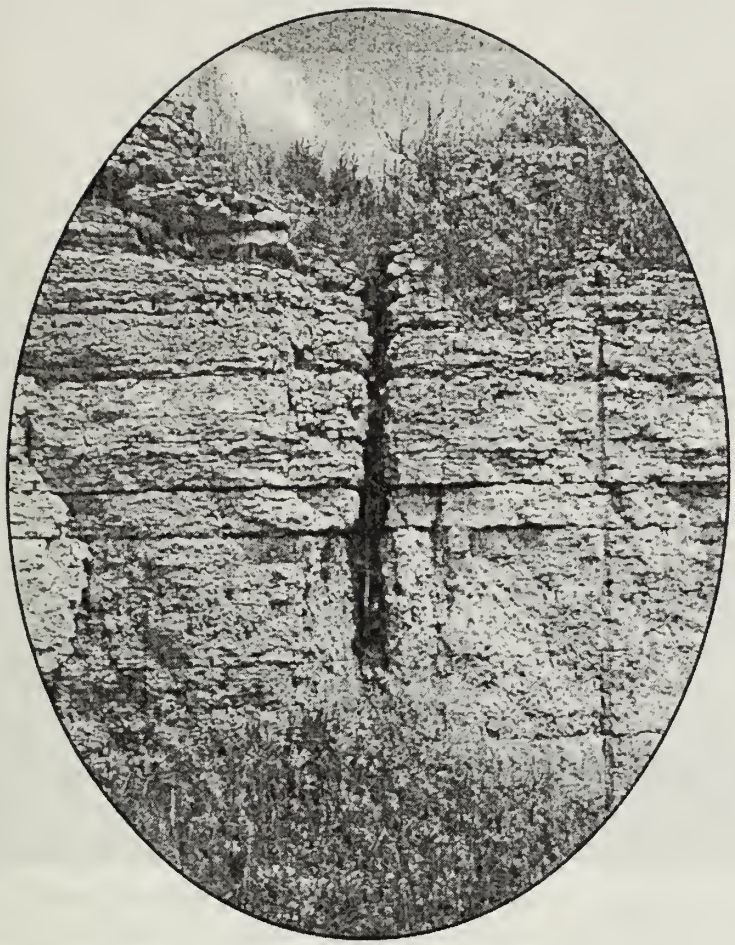


Figure 5. *Karst bedrock exposed in a road cut shows a crevice up to about 1 foot wide. Crevices typically range from 6 inches to 1 foot in width in the sinkhole plain, and are large enough to allow soil to fall into them. If the soil falling into the crevice is washed away by flowing groundwater, a sinkhole will probably form over the crevice.*

duits. The cold and slightly acidic water enlarged the conduits on a continual basis. As the conduits increased in size, larger and larger volumes of water entered the underground drainage system, further increasing the diameter of the conduits. With time, the horizontal conduits slowly increased in size until they were large enough to allow human entry; the conduits were then a branchwork-type cave. Dissolution and erosion of the cave walls and floor continues today; the presence of the cave stream is evidence of that fact.

In the early stages of conduit enlargement, the largest conduit began to receive more and more of the available groundwater. Consequently, it grew (its walls dissolved) at a faster rate; in doing so, it became a sink or drain for the area it traversed. As it grew and became more efficient at moving groundwater, the water table over the large conduit dropped lower and lower. Eventually the water table became so low that an air space formed above the water flowing through some of the conduits. Initially, an air space may have been present only for a short period of time during the driest parts of the year. But as the conduits enlarged, the air space formed more frequently until there was an air space above the cave stream more often than not. At that point, water seeping into the cave from the surface through circuitous routes through the bedrock could have begun to form stalactites and flowstone. These processes continue today at Illinois Caverns and may be seen wherever water is seen entering the cave from the ceiling or the walls.

Figure 6. *Large sinkholes can form rapidly. This sinkhole was about 25 feet in diameter and about 30 feet deep and formed at the bottom of a small lake during a 9-inch rainfall event in southwestern Illinois. The lake and its fish disappeared into a small cave passage at the bottom of the sinkhole that was part of the shallow karst aquifer. The white rocks represent the top of bedrock and are made of very pure limestone.*

The Hydrologic Cycle In Karst Terrain

The Hydrologic Cycle

During the Hydrologic Cycle, water at or beneath the Earth's surface constantly cycles through the ocean, atmosphere, and land. Water evaporates from the surface of an ocean, sea, or large lake and rises into the atmosphere as water vapor. As the water vapor rises, it cools and condenses in the atmosphere, and forms clouds. The clouds which move with the prevailing winds eventually travel over continents. Unstable conditions due to temperature changes and mixing air masses cause the clouds to lose some of their water vapor as rain or snow.

When rain or snow falls on the ground, much of the water seeps into the pores of the soil and begins to saturate it. If the rainfall continues or the snow continues to melt, the soil becomes saturated and water that cannot seep into the soil runs off into low-lying areas that typically contain streams. The small streams flow toward lower areas and empty into larger streams that eventually take the water back to the oceans, seas, or lakes (Figure 7).

The water that remains in the saturated soil will either enter an aquifer, be used by plants, or evaporate. Aquifers in many parts of Illinois are composed of sand and gravel layers. Water from an aquifer may supply water to streams on a regular and long-term basis. Plants take up

water and dissolved nutrients; much of this water is given off as evapotranspiration. Water that doesn't enter an aquifer evaporates from the soil to rejoin the atmosphere as water vapor.

The Karst Hydrologic Cycle

In the Karst Hydrologic Cycle, water encounters the land surface, seeps into and saturates the soil. Any excess water runs off to low-lying areas. Water seeping into the soil feeds the underlying aquifer, is taken up by plants, or is lost via evapotranspiration and evaporation. So far, this is the same as the hydrologic cycle discussed above.

What makes the karst hydrologic cycle different is that there are few, if any, surface streams in karst regions. Surface runoff generally flows into sinkholes and immediately enters the karst aquifer (Figure 8). Once the water enters the aquifer it is referred to as groundwater. After entering the karst aquifer, the water flows underground through near-vertical crevices, between the bedding planes of the limestone and/or dolomite, and through small conduits and caves (Figure 9).

Groundwater from a karst aquifer may only be hours to a few years old, which is very different from other bedrock or sand and gravel aquifers found elsewhere in Illinois. Eventually, most of the groundwater discharges from the karst conduit system at a spring (Figure 10). Springs can actually form the stream headwater in some places. Stream water empties into increasingly larger bodies of water. For example, in the case of Illinois Caverns, the cave water discharges from Dye Spring, enters Horse Creek, then the Kaskaskia River, then the Mississippi River and finally the Gulf of Mexico where it continues the cycle (Figure 11).

Suggested Questions

How does the hydrologic cycle in central Illinois differ from the karst area of southwestern Illinois where there are few surface streams?

Because surface runoff flows directly into the karst aquifer, what would happen to contaminants, such as motor oil or sewage, dumped onto the surface?

What will happen to loose soil during and following a large rain storm?

How might contaminants and loose soil affect the water quality of the cave stream and springs in the area?

Will the quality of cave and spring water be better, worse, or the same as that of surface water?

What dangers exist in Illinois Caverns or any cave during a large rain storm?

Looking at the diagram of the Karst Hydrologic Cycle determine what percentage of rainfall would cascade down into the cave from sinkholes?

What role does vegetation play in controlling the volume of water recharging the karst aquifer and what effect does it have on the degree of soil erosion?

When exploring Illinois Caverns, you can see water flowing into the cave from the ceiling. Where is that water coming from and how old do you think it is? Would you expect the flow rate to stay the same or increase following a large rainfall?

The stream in Illinois Caverns flows all year long. Why? Where does the water come from?

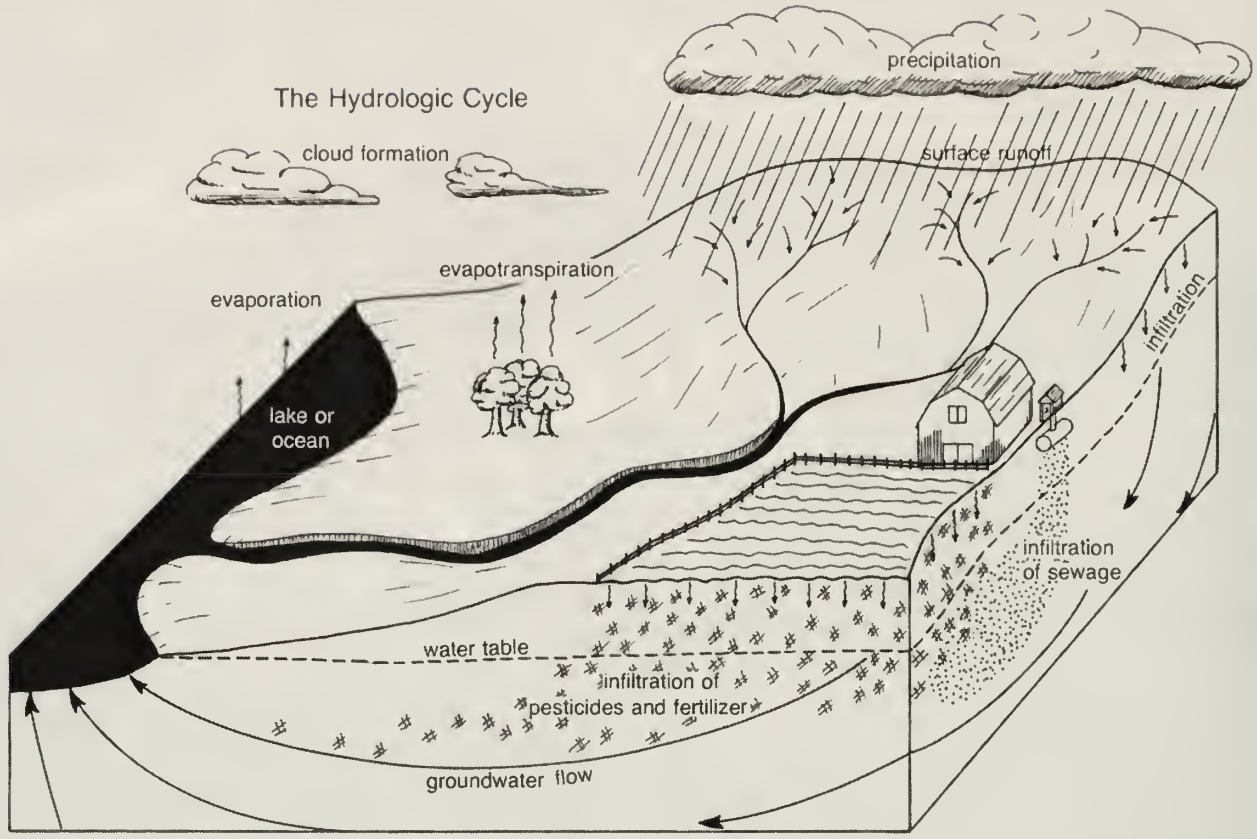


Figure 7. *The hydrologic cycle in a non-karst terrain showing the cyclical nature of the evaporation of water from large bodies, and the formation of clouds that give up their moisture over land masses (as snow and rain). A portion of the precipitation runs off the land surface, seeps into the ground, evaporates, and is taken up by vegetation that loses moisture due to a process called evapotraspiration.*

***Figure 8**. Watersheds in most parts of Illinois (top) have dendritic drainage patterns that channel surface runoff to small streams. Watersheds in karst terrain (bottom) are truncated by sinkholes where surface runoff is channeled underground to the karst aquifer and ultimately to reemerge into a surface stream. The runoff from both areas eventually joins the Mississippi River and discharges into the Gulf of Mexico where it continues the cycle.*

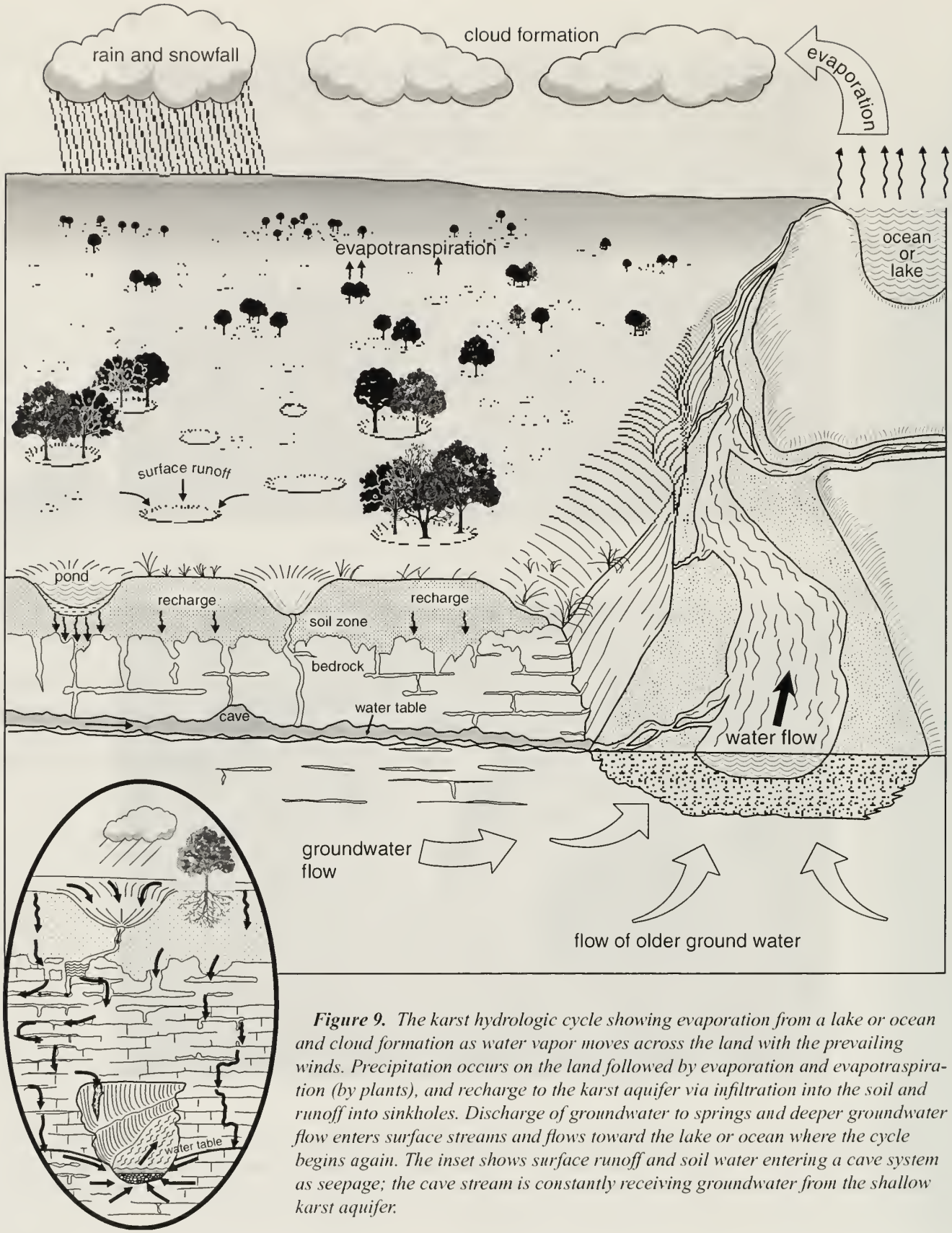


Figure 9. *The karst hydrologic cycle showing evaporation from a lake or ocean and cloud formation as water vapor moves across the land with the prevailing winds. Precipitation occurs on the land followed by evaporation and evapotraspiration (by plants), and recharge to the karst aquifer via infiltration into the soil and runoff into sinkholes. Discharge of groundwater to springs and deeper groundwater flow enters surface streams and flows toward the lake or ocean where the cycle begins again. The inset shows surface runoff and soil water entering a cave system as seepage; the cave stream is constantly receiving groundwater from the shallow karst aquifer.*

Figure 10. *Some springs discharge from limestone bluffs that border the Mississippi River. This picturesque spring, called Falling Springs, is located near Dupo, Illinois and drains part of the northern portion of the sinkhole plain.*

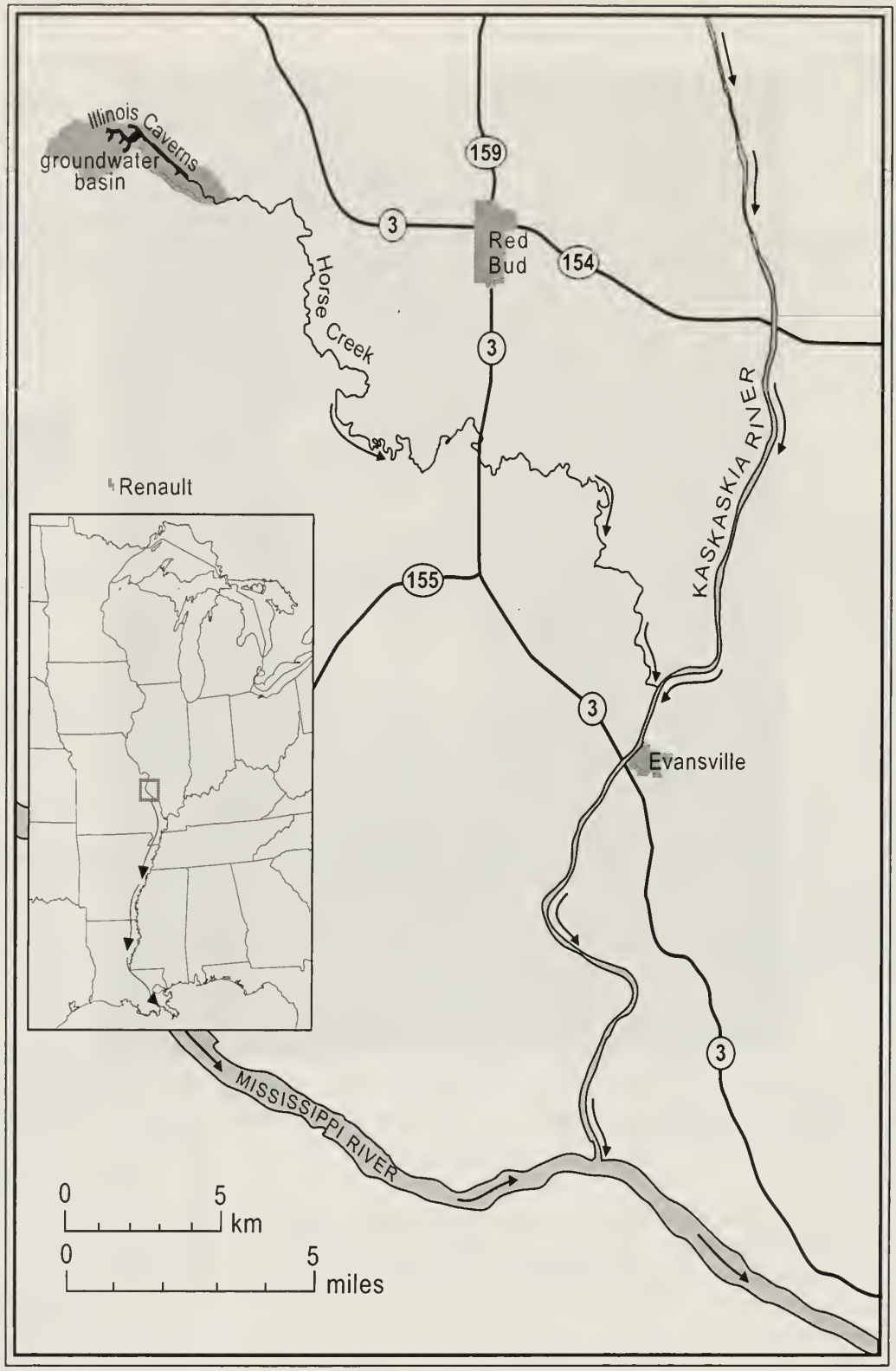


Figure 11. *Map of the drainage of the Illinois Caverns groundwater basin, where it discharges along Horse Creek, enters the flow of the Kaskaskia River, and ultimately the Mississippi River. The inset map shows the Mississippi River discharging into the Gulf Coast in Louisiana. Thus, the water entering and flowing through Illinois Caverns eventually endus up in the Gulf Coast.*

The Cave Stream

One of the main features in Illinois Caverns is the cave stream. The dynamic nature of the cave stream makes it an integral and extremely important part of the cave and its ecosystem. The stream provides habitat for many of the organisms that inhabits the cave and helps maintain constant temperature and humidity conditions within the cave. The stream played a big part in forming the cave in the past and continues to shape and alter the cave in the present, continuing to enlarge the cave and creating features along its pathway. The stream grows and changes by dissolving limestone bedrock, and by moving sediment, and depositing sediment throughout the cave.

Cave Stream and Cave Formation

The cave stream started out as a small trickle of surface water that combined with water seeping through the soil. The water flowed into a crevice in limestone bedrock, traveled along bedding planes, and moved toward a small spring or stream bottom. Inflowing water continued to dissolve the limestone for tens of thousands of years and eventually a cave was formed. Water still flows through the cave and Illinois Caverns is still growing. The top of the original bedding plane along which the cave began to form is now part of the ceiling at Illinois Caverns.

Cave Enlargement and Sediment

Deposits of sand, gravel, and fine silt left by the stream are common throughout the cave. These deposits are clues to how fast the cave stream is moving at various times and how much sediment the stream is carrying. A fast moving stream has a lot of energy and can carry larger particles of sediment which can abrade the cave floor and walls like sandpaper against wood. The higher the energy of the stream(the faster the water flows), the larger the sediment particles it can carry. For example, a flood in the cave might be able to move stream cobbles up to 1 foot in diameter. A slow flowing stream may be able to carry only very small particles (about the size of flour particles). Thus, when you see large, rounded rocks in the cave stream, or in any surface stream, consider how much energy it would take for the stream to move that rock.

Cave Features

Numerous features seen in the cave are due to the actions of the cave stream. The stream has the ability to dissolve bedrock and provide the energy necessary to carry sediments. Features such as scallops, potholes, partially collapsed stalagmites, and many more can be seen in Illinois Caverns. (See *Cave Deposits Information Sheet* for more information).

Scallops. Scallops are indentations in the rock and look like someone took an ice cream scoop and scooped out portions of the rock (Figure 12). Scallops are common where the stream flows across rock faces and are due to dissolution of limestone by running water. They are found both on the stream walls and on the bed of the stream. The size of scallops may be used to determine how fast the water is flowing and in what direction. Large scallops (up to a foot across) form in slow moving water. Small scallops (an inch or

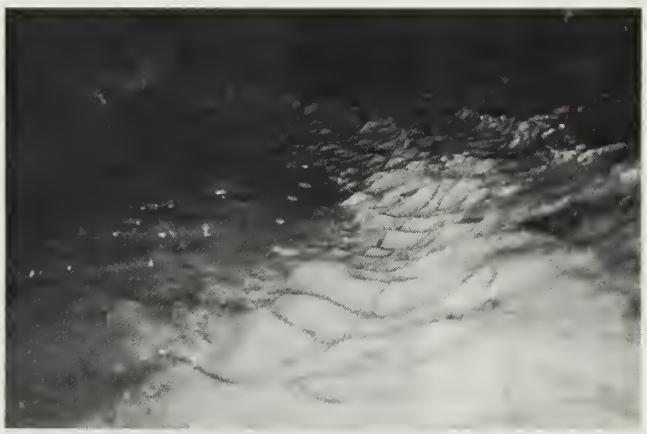


Figure 12. *Scallops are commonly seen in Illinois Caverns and their formation records the rate of water flowing through the cave.*

less across) form in fast moving water.

Potholes. Potholes are bowl-shaped depressions located in the floor of the stream (Figure 13). These features form when cobbles or pebbles become trapped in small depressions in the limestone bed. During flooding, eddy currents from flowing water cause the cobbles and pebbles to swirl in a circular motion. Over hundreds to thousands of years the rocks swirling around create a bowl-shaped depression that may range from 4 to 12 inches in diameter and can be 4 to 6 inches deep.

Figure 13. *Numerous potholes in a relatively soft layer of rock form a jagged ledge adjacent to the cave stream. This is a good example of physical erosion within the cave.*

Manganese Oxide. You may observe many black rocks in the stream as you travel through Illinois Caverns (Figure 14). These rocks are coated with a material called manganese oxide. Manganese is a metal that is dissolved in groundwater when the water is isolated from the atmosphere. The groundwater has low oxygen content because it is not in contact with the surface atmosphere. This is an ideal environment for manganese to dissolve from minerals that are present in the soil zone and the bedrock. As groundwater seeps into the cave, it is exposed to oxygen again and the dissolved manganese precipitates (becomes a solid again) as an oxide that coats rock surfaces.

Stream-Dependent Cave Biota. The aquatic biota living in the cave stream depends on the stream for their existence. Cave-adapted organisms like amphipods, isopods, and salamanders (Figure 15) and accidental organisms like fish, turtles, snakes, frogs, clams, and terrestrial salamanders can be found in the cave (Figure 16).

Figure 14. *Science teachers walk through a rain-swollen cave stream while looking for aquatic organisms and check water quality in Illinois Caverns during a workshop in 1995. The rocks just above the water line are blackened by a thin manganese oxide coating. This black line is an indicator of recent flood levels. Please be aware that visitors wearing shorts and canvas shoes will no longer be allowed into the cave. Make sure you and your students dress appropriately.*

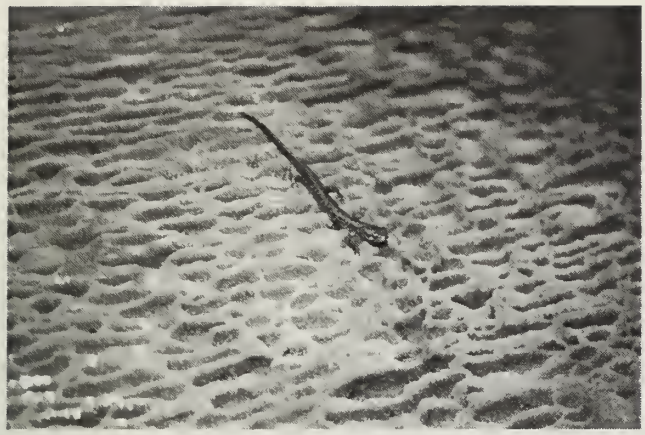


Figure 15. *The troglobitic orange and black spotted salamander (Eurycea lucifiga) is a common sight in Illinois Caverns and is seen here on the water-filled microterracettes of a large stalagmite near Capitol Dome.*

Figure 16. *A small toad, probably washed into the cave during a large rainfall event, sits on a rock slab in the dark.*

Organisms are often washed into the cave with runoff from large rainstorms, or they may crawl or accidentally fall through a sinkhole and into the cave where they may spend the rest of their (probably shortened) lives.

Suggested Questions

Where are the scallops and potholes located and why?

Why don't we see any scallops on the ceiling of the cave?

Why are the accidental organisms in the cave predominantly water-dwelling organisms?

What mechanisms could be responsible for stalagmites collapsing and leaning toward the stream?

Cave Deposits Of Illinois Caverns

There are numerous deposits of materials in the cave that you should notice and examine while exploring Illinois Caverns. These deposits yield clues to the physical and chemical processes that took place in the cave in the past and are taking place today. These processes continue to modify the size, shape, and appearance of the cave.

Cave deposits consist of two types of material: 1) sedimentary materials brought in by water, and debris that is physically brought into the cave by gravity (e.g., by sinkhole formation or wall/ceiling collapse); 2) mineral deposits (typically calcite) that are precipitated from groundwater saturated with the mineral calcite that seeps into the cave from overlying or adjacent bedrock (Figure 17).

Sedimentary Deposits

Thick deposits of sediments and remnants of similar deposits found in Illinois Caverns and nearby caves are clues to erosion and flooding that occurred in the caves tens of thousands of years ago. Fine silt and clay materials that often are found on one side of the wider cave passage of Illinois Caverns were brought into the cave by flood waters. As energetic/turbulent flood waters lost some of their energy within the cave passages, they dropped the sediment they were carrying. Recent determinations of the ages of some of these sediments has given us insight into when these deposits were formed and their significance.

Between 30,000 and 20,000 years ago, climatic conditions in southern Illinois were far different

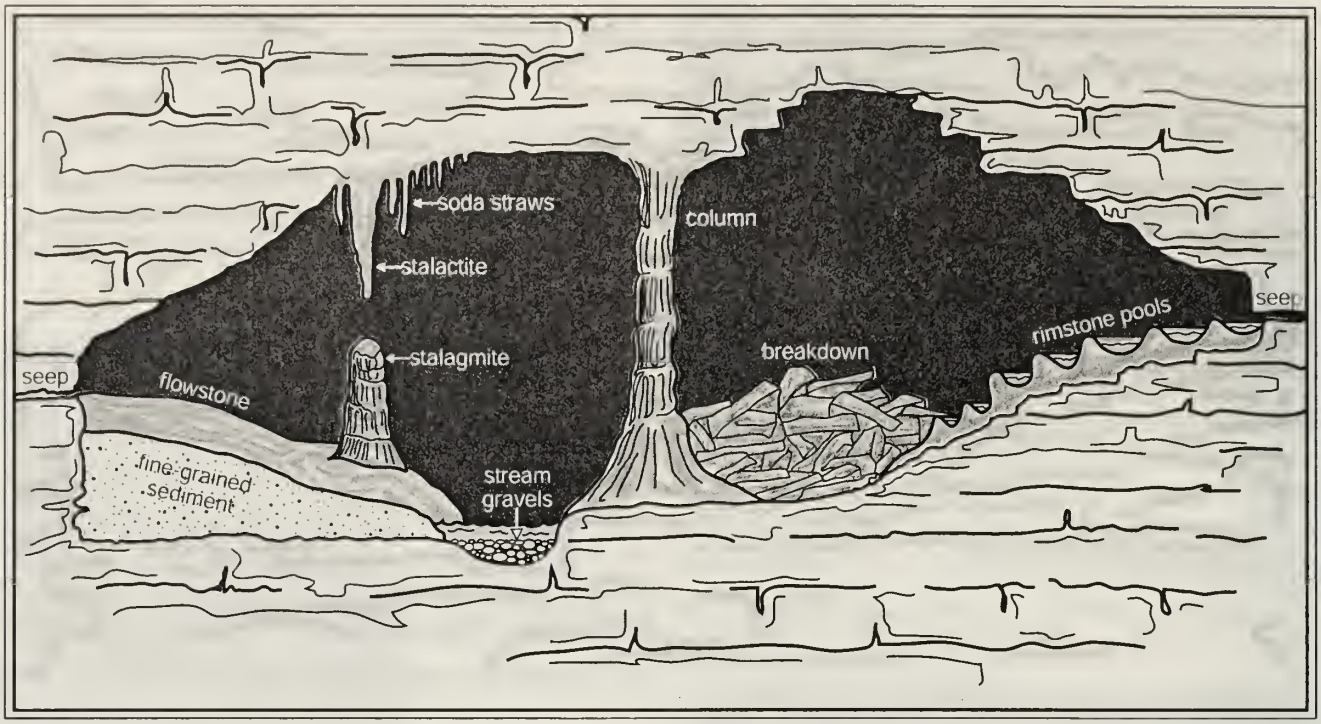


Figure 17*. Cave deposits are numerous and varied. They include speleothems (stalactites, stalagmites, columns, flowstone, rimstone pools) and sedimentary-type deposits (large slabs of breakdown, smaller stream gravels, and very fine-grained sediment). Combinations of these deposits can complicate their appearance.*

than those of today; a continent-wide glacier of the Wisconsin glacial episode began to move into northern Illinois. Related dryer conditions in southwestern Illinois are suspected of accelerating surface-erosion rates due to the lack of ground cover. When it did rain and/or during periods of snow melt, surface erosion was significant and caves in this area were partially to almost completely filled with the silty soil seen on the surface. Later erosion by the cave stream reopened most of the caves and left remnants of the silty soil throughout. These sediments are commonly seen on only one side of the main passage and form steep slopes, or may be part of the trail worn into the sediment by visitors. Today, only small amounts of fine sediment are deposited in the caves during and immediately following large rainfall events.

Deposits of sand and gravel may be seen in some places high above the finer-grained stream deposits. These coarse deposits are remnants of the bed of the cave stream tens of thousands of years ago, when the stream level was much higher, the cave passages were much smaller, and the cave stream energy was much greater.

Breakdown and sidewall collapse are also types of sedimentary deposits. Fragments of the bedrock collapsed from the sidewalls or from the ceiling can pile up almost anywhere in the cave. Breakdown piles may form mounds in the middle of the cave passage. Capitol Dome is located on one such mound, which really is a large pile of breakdown, covered in sediment, that now occupies the center of the cave.

Speleothems

A speleothem is a secondary mineral deposit found in caves. Stalactites, stalagmites, and flowstone are all examples of speleothems (Figure 18). A secondary mineral deposit is a feature that formed after the cave formed. Speleothems are abundant in Illinois Caverns and add to the beauty and complexity of the cave.

Many questions surround the mystery of spe-

Figure 18. *Columns are well named because of their ornate nature and natural fluting.*

leothems. Why do stalactites look like icicles and do they form the same way? How long does it take for stalactites and stalagmites to grow to their present size? Why are they different colors? Why are they shaped the way they are?

Caves often contain mineral deposits that have formed very quickly relative to other natural processes involving rocks and minerals. This is because carbonate rocks such as limestone dissolve easily in normally acidic rainwater and especially more acidic soil water. Rainwater contains relatively high concentrations of carbon dioxide from the air. Soil water contains even more carbon dioxide derived from the breakdown of organic materials by bacteria in soil. The carbon dioxide combines with water and forms carbonic acid, which dissolves limestone bedrock. Soil water can hold a significant amount of dissolved calcium carbonate because the soil zone is under a higher gas pressure than the atmosphere (a cave is under atmospheric pressure). Carbon dioxide-charged soil water can hold much more calcium carbonate in solution (in a dissolved state) than it can at atmospheric pressure. Thus, when soil water seeps down into the bedrock overlying a cave and if time permits, it dissolves as much calcium carbonate as it can

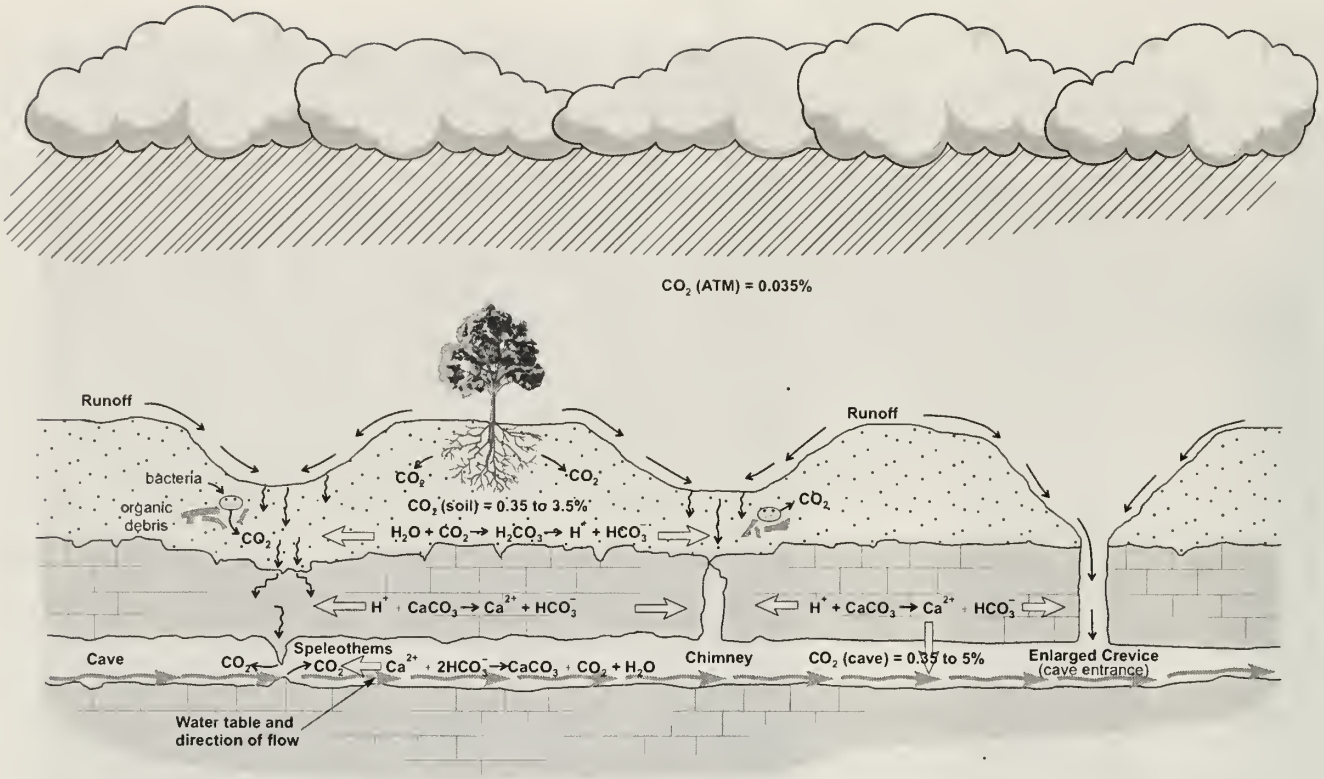


Figure 19. *Carbon dioxide (CO_2) and water (H_2O) are the key ingredients for the dissolution and precipitation of minerals like calcite and dolomite that make up carbonate rocks. Here, sinkholes are focusing runoff to a relatively small area where it can begin its journey to a cave below. Carbon dioxide from the atmosphere and, to a greater extent, from the soil zone, dissolves in water and forms carbonic acid (H_2CO_3). This, in turn, interacts with bedrock limestone ($CaCO_3$) and dissolves the rock. This action can create enlarged fractures, cave and chimneys. If the flow of water through the bedrock, prior to entering the cave, is slow (a matter of several days to 1 week), then speleothems (stalactites, stalagmites, flowstone and rimstone pools) will form as the water enters the ceiling or walls of a cave and the lower pressure (atmospheric) results in the release of carbon dioxide (especially if there is splashing or agitation). If soil water enters a crevice and gets a fast ride to the cave in a day or less, then it will dissolve the crevice walls to form a chimney.*

hold. When the water eventually breaks through into a cave along a fracture, the pressure on the water is rapidly lowered and some of the carbon dioxide in solution is released in a manner similar (but less dramatic) to opening a bottle or can of a carbonated beverage (Figures 19 and 20).

When the water flows down a cave wall or a slope, it may precipitate flowstone. The rate of formation of these features may increase as the water is agitated or splashed. Splashing increases precipitation because agitation of the water causes the carbon dioxide to be released at a faster rate, just like a shaken carbonated beverage. The formation of rimstone pools is similar to that of other speleothems in that they start out as a stream of groundwater flowing over an uneven bedrock stream. Every time the water flows over a prominent surface, the water splashes and calcite precipitates on the high points. Eventually, the calcite forms tall ridges that begin to act as dams; these are the rimstone pools.

The water flowing into the cave loses the acidity produced by the dissolved carbon dioxide. Because the water cannot hold as much calcium carbonate in solution as it once could, calcium carbonate, generally in the form of the mineral calcite, begins to come out of solution, a process called precipitation. Crystals of calcite grow on cave surfaces and on other crystal surfaces. Where such water seeps from the ceiling, sta-

Figure 20. *Opening a bottle of carbonated water shows the effects of degassing. If you monitor the pH of the carbonated water while it fizzes, you will notice the pH decreases with the loss of carbon dioxide. If the water in the photograph were saturated with calcite, the calcite would precipitate in the bottle just as it does on the walls, ceiling and floors of Illinois Caverns.*

lactites form. Where the water drips onto the floor, stalagmites form. When a stalactite and stalagmite meet, they form a column (Figure 21). An example of both the effects of agitation and column formation is located behind Capitol Dome. You may notice that the stalactites over the large stalagmite just behind Capitol Dome are much smaller than the stalagmite. This is due to the splashing and additional degassing that occurs where the mineral-laden water drops hit the ground. Eventually the stalactite and stalagmite may join to form a column (provided the water supply is not diverted or stopped entirely). Stalactites and stalagmites are similar in shape and size to icicles and ice stalagmites that form by a temperature-driven mechanism (Figures 22 and 23).

The rates of formation of cave minerals such as calcite in the sinkhole plain can be as rapid as 0.002 inches per year at Falling Springs near Columbia, IL (to the north of Illinois Caverns). That means that in 100 years, the flowstone at Falling Springs can grow to a thickness of 0.2 inches. Growth rates for speleothems vary greatly from location to location and with time, but an average rate for speleothem growth is 1.5 inches in 100 years. Stalactites near the entrance of Illinois Caverns that were probably broken off when visitors first explored the cave about 100 years ago have only regrown about 1 inch.

Speleothems range in color from white to brown and black. In addition, thin portions of speleothems may be translucent and in some cases almost transparent. Brown is the most common color for speleothems. The brown coloration is due the incorporation of organic acids, picked up by water in the soil zone, within the growing crystals. Another process that may color speleothems brown is cave flooding. Periodic cave flooding can cover speleothems with mud, which becomes trapped beneath the next layer of calcite. Black speleothems form when they are coated with manganese oxide. Manganese is a metal that is found dissolved in groundwater that contains little or no dissolved oxygen, and precipitates from the water upon exposure to the oxygen within a cave environment. The light source you are carrying while exploring a cave can affect the apparent color of the speleothems underground. The color of a speleothem that one sees also depends on the color and brightness of the light one shines on them. The sun-like brilliance of a photographic flash may reveal subtle color differences that may not be discernible in the light from an ordinary incandescent bulb of a flashlight. Speleothem colors also may appear different in the bluish glow from a battery-powered fluorescent light, and speleothems may fluoresce under an ultraviolet lamp.

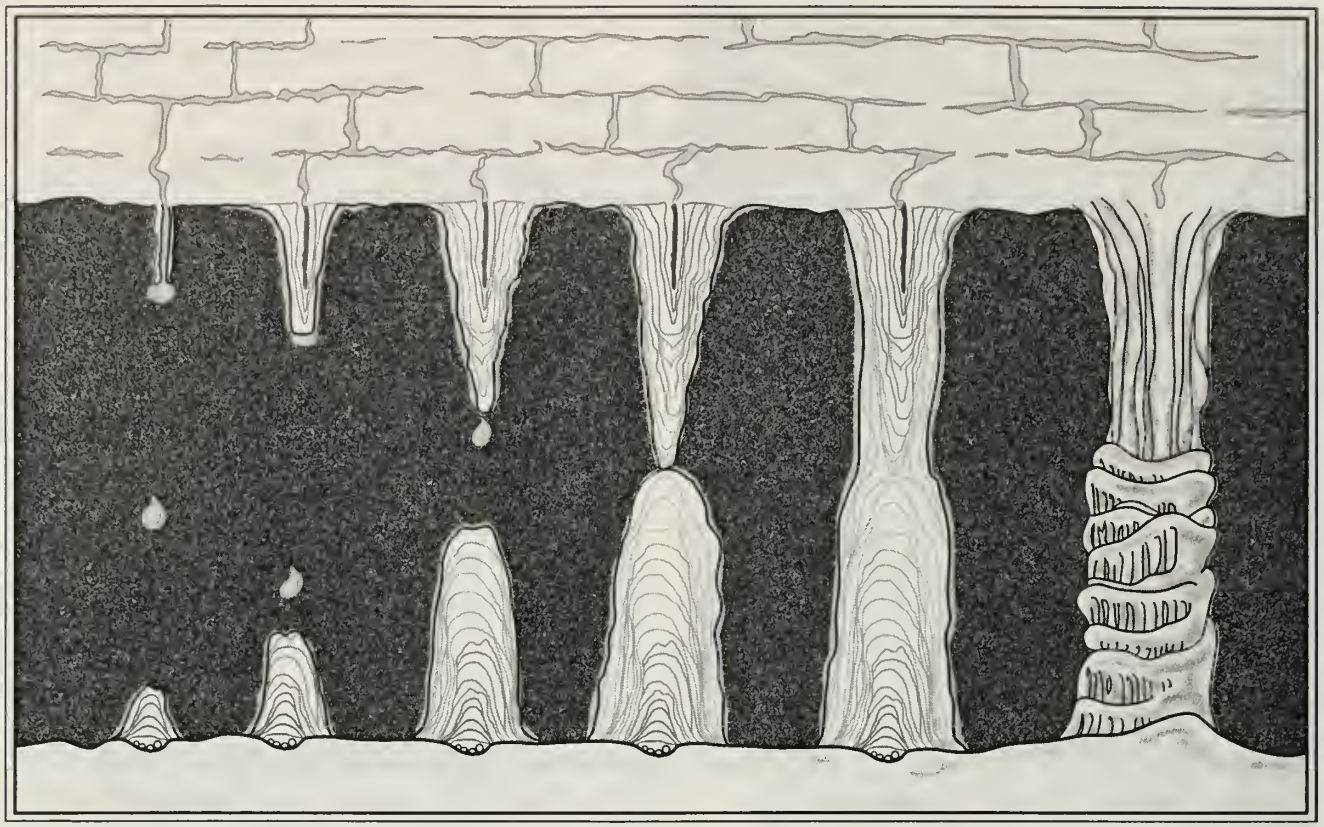


Figure 21. *This is a step-by-step sequence of speleothem formation showing the internal layering of each step. Initially, soda straws form on the ceiling and water drips through their center. Stalagmites begin as small "cave pearl"-filled depressions on the floor of the cave, and grow into small, knob-shaped formations. With time, the stalactite and stalagmite grow closer and closer, until they meet to form a column (shown internally and externally).*

Suggested Questions

What relationship does the energy of a stream have to the size of sediment it is capable of transporting?

What role did the collapse of parts of the cave's ceiling and walls have on the evolution and appearance of Illinois Caverns?

What role did former climatic conditions in southern Illinois (during the Pleistocene epoch) have on the deposition of fine sediment in Illinois Caverns?

Why do speleothems form in caves? That is, what processes make it possible for speleothems to form?

Why is carbon dioxide important to speleothem formation?

Why do stalactites look like icicles? Do stalactites and icicles form in the same way? How does their formation differ?

What controls the color of speleothems? Do you think the colors change with time? Why?

At what rate do speleothems form? To what length would you expect a stalactite to grow in your lifetime assuming a growth rate of 1 inch/100 years and that you live to the age of 85?

Suggested References

A superb reference for examining and understanding speleothems is "Cave minerals of the world" by C. Hill and P. Forti, published by the National Speleological Society, Inc. This 463 page book contains an encyclopedic compilation

Figure 22. *Icicles are similar to stalactites in their shape; however, they form in a somewhat different manner. Warming of ice and snow on a roof (by the sun or heat from a building) causes melting and a flow of water to the edge of the building where it may slowly drip to the ground. If the dripping occurs in a shaded area, then the water can refreeze and form a stalactite-like feature or features. True stalactites form by precipitation of the mineral calcite through degassing or loss of carbon dioxide.*

of the best examples of speleothems in the world, and the photographs are numerous and spectacular.

The Directional Trend And Cross Sectional Shape Of Cave Passages

The trend of cave passages (sinuous or straight) and their cross-sectional shape also yield information about the origin and history of the cave. Events that occurred during the cave's development change its geometry and leave a record of the past.

Figure 23. *Ice stalagmites may be found near the entrance of caves or mines during the winter in the Midwestern US. These bamboo-shaped stalagmites formed near the entrance of a limestone mine near Utica, IL; each are about 1 to 1½ feet tall. They formed when water flowing through the warmer overlying soil and rock seeped into the cave and froze upon landing on the cold rocks and encountering the sub-freezing winter temperatures near the mine's entrance.*

Sinuosity of the Cave

The directional trend of cave passages can be either straight or sinuous. The straight passages form where caves develop by expanding preexisting fracture traces; sinuous passages form where caves develop from anastamoses that form along bedding plane partings. Illinois Caverns is not straight like a train tunnel, but more sinuous like a stream valley. The reason goes back to the origin of the cave.

When Illinois Caverns first began to form, it consisted of a stream of water that found its way about 30 feet into bedrock and began to flow laterally along a relatively wide bedding plain in the rock. As it flowed, the water dissolved small amounts of limestone, cutting a tube that got larger and larger. Downcutting of the tube eventually expanded the opening in the rock to cave-size (large enough for a human to crawl into for some distance). The pathway the water

initially took along the bedding plain is similar to the pathway a small stream of water follows when flowing down a car windshield. The pathway is almost never a completely straight line, but generally follows one direction. In the example of water on a windshield, the water flows sinuously from the top of the window (a higher elevation) to the bottom of the window (a lower elevation). The flow direction is driven by gravity. This is the same mechanism for groundwater flow along the bedding planes of limestone bedrock.

Cross Sectional Shapes of Cave Passages

The cross sectional shape of cave passages yields another piece of information about the origin of the cave. A cross section shows a vertical slice of the earth in an area, just like a piece of cake shows the different layers of cake and frosting. Caves initially form in bedrock that is either partially filled or totally filled with groundwater. Caves that form under partially filled conditions are known as vadose caves and caves that form completely underwater are referred to as phreatic caves. Vadose conditions occur when groundwater flows through fractures and along bedding planes with an air space above the water, dissolving the rock in a downward direction. Phreatic conditions are present when groundwater totally the fractures and bedding planes through which it flows, dissolving the rock equally in all directions.

There are two basic cross-sectional shapes of cave passages: The canyon and the ellipse (Figure 24 and 25). The canyon is formed under vadose conditions and appears as a narrow passage with a high ceiling. A variation on this is a rectangular-shaped passage that is nothing more than a wide canyon. An ellipse, formed under phreatic conditions, appears as a horizontal tube. A modification of the ellipse is the keyhole where formerly phreatic conditions have given way to vadose conditions and a canyon-like down cutting has occurred in the floor of the tube.

A cave stream like the one in Illinois Caverns flows down vadose-type passages and dissolves downward, making the cave deeper and, relatively speaking, the ceiling higher. There are numerous modifications to this shape that include a channel or notch in the ceiling, ceiling collapse and breakdown, sediment fill, speleothem formation, and the development of multilevel passages. The ceiling channel may be a remnant of the original channel through the bedding plane, or it may have been formed subsequent to the filling of the cave with sediment and the formation of a channel between the sediment and the ceiling (Rimstone River is a good example of this type of modification). Ceiling collapse and the formation of breakdown results in a dome-shaped ceiling and a rubble-strewn floor that is often elevated above the trend of the cave. The deposition of fine sediment can modify the cave passage shape often resulting in a slope of fine sediments on one side of the cave. Subsequent deposition of speleothems further complicates the shape of the cave. Multilevel passages in Illinois Caverns are often formed by the deposition of flowstone on top of a sediment fill that later is removed. The result is a bridge of flowstone across the cave (the entrance to the mushroom passage is a good example of this type of modification.

CLASSROOM ACTIVITIES

Create A Karst Terrain Map

Objective:

Improve understanding of karst topography and how karst affects land-use planning decisions in an area. To familiarize students with topographic maps and reinforce basic topographic skills learned in other lessons.

Background:

The distinctive hydrology and landforms of karst terrain arise from the combination of the high degree of solubility of carbonate rock and

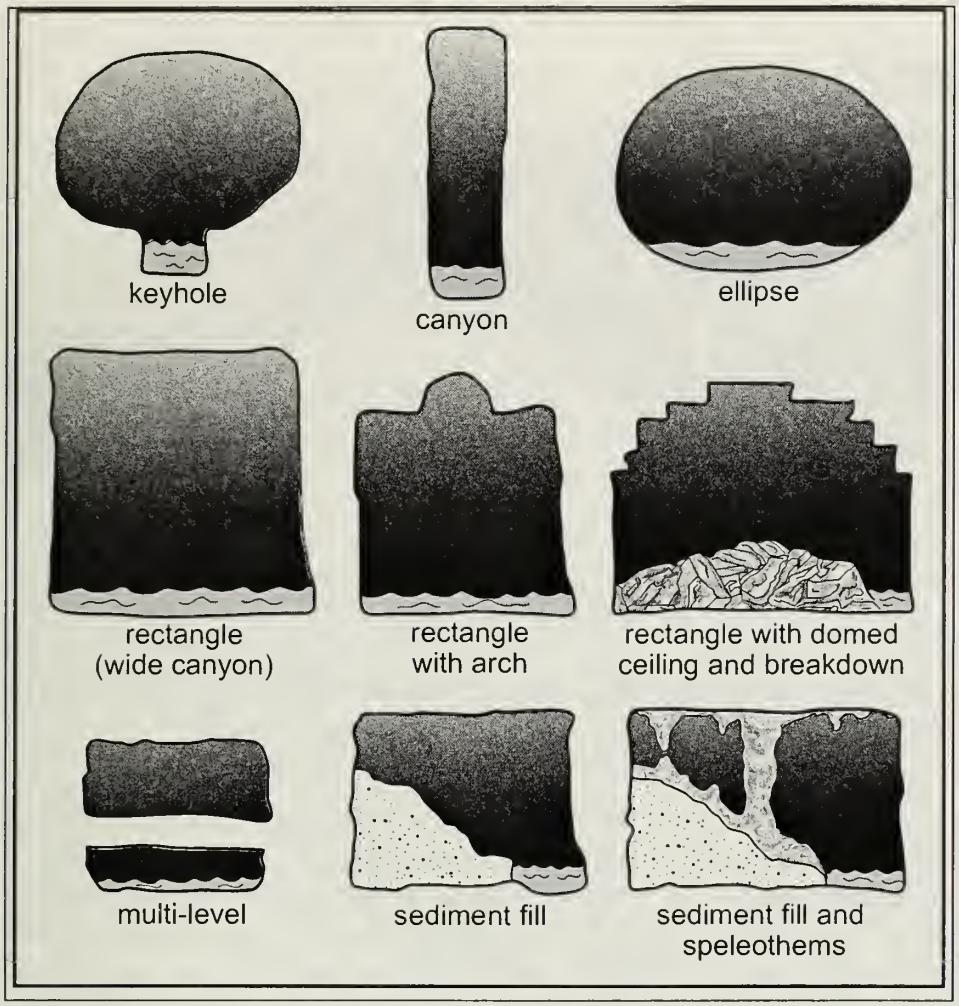


Figure 24. *Cross sectional shapes of cave passages can tell you much about their origin and evolution. Here are 9 passage shapes that may be found in Illinois Caverns. The rectangular shapes (including the canyon) are formed by water flowing through bedrock with an air space above the water. The ellipse shape is formed when the passage is completely filled with water. Combinations of these two conditions, and filling of the cave with sediment and/or speleothems can significantly alter these shapes.*

Figure 25*. These are examples of cross sectional shapes that may be seen in Illinois Caverns. They include (from left to right): keyhole (Canyon Passage), canyon (Canyon Passage), rectangle with arch (Rimstone River), rectangle with domed ceiling and breakdown (Breakdown Room), multi-level (Canyon Passage), and sediment fill with speleothems (The Dragon).*

Figure 26. *Location map for the Geologic Mysteries of Illinois Caverns. Clues to Mystery 3 (Human Visitation) can be seen throughout the cave, especially in the first few thousand feet.*

the well-developed porosity and permeability. Porosity in carbonate rock is due to abundant, near-vertical fractures and horizontal conduits along numerous bedding planes. Typical karst features include topographic depressions (sinkholes), caves, and large springs, fluted rock outcrops, blind valleys, and swallow holes. Karst terrain occurs in Illinois where the bedrock lithology consists of carbonate rocks (limestone and dolomite) and the overlying drift (glacial material) thickness is less than 50 feet. Carbonate bedrock underlies approximately 25% of the state's surface, which can be seen by studying a geologic map of Illinois. The groundwater in karst regions, particularly in areas with many sinkholes, is considered very susceptible to contamination. Susceptibility to contamination of an aquifer depends on the thickness and permeability of the overlying sediments. Where bedrock is susceptible to karstification and the overlying drift is thin, shallow aquifers in the bedrock have a high susceptibility for contamination.

Karst terrain has unique characteristics, which generally can be identified by looking at topographic maps. Assumptions can be made about the underlying geology by observing the abundance of karst land forms. Students should be familiar with the concept of karst terrain, land forms associated with karst, and sinkhole formation. Topographic map skills and an understanding of map symbols are also needed.

Terms – karst, sinkhole, sinkhole plain, limestone, carbonate, topographic map

Materials:

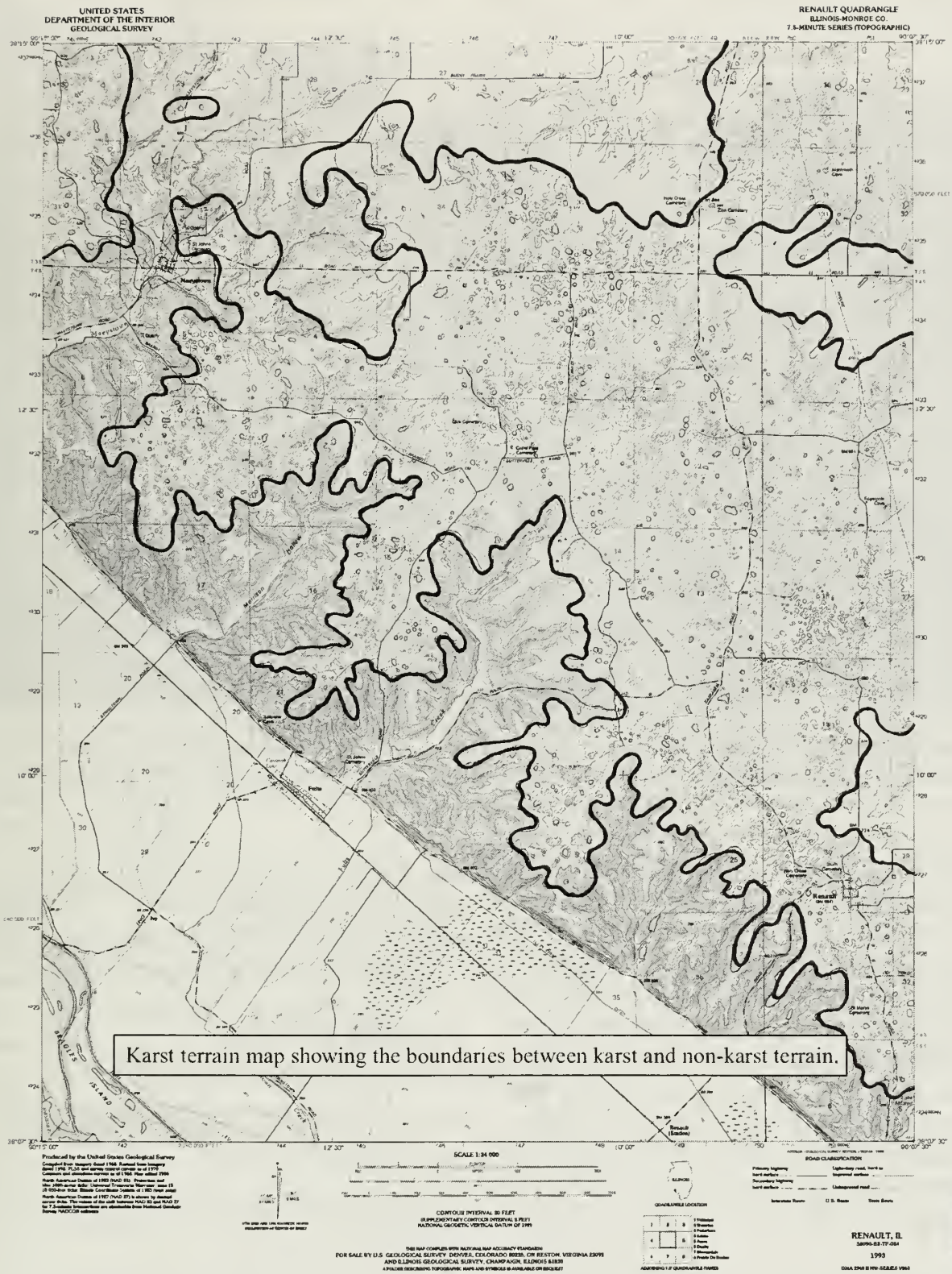
One set of laminated US Geological Survey 7.5 minute quadrangle maps for each student group
Map Set: Waterloo, IL and Renault, IL

Dry erase markers for each group

For reference or display:

Geologic Map of Illinois. Illinois State Geological Survey. H.B. Willman et al., 1967.

Karst Terrains and Carbonate Bedrock in Illinois. Illinois State Geological Survey I-Map Series 8. C.Pius Weibel and Samuel V. Panno, 1997.



Karst terrain map showing the boundaries between karst and non-karst terrain.

Procedure

Provide each group with a laminated map set and instruct the students to draw lines around clusters of sinkholes. Do this for all of the sinkholes. Make sure the line around the sinkhole cluster is ½ mile from the nearest sinkhole to create a buffer zone that might include sinkholes that do not show up on the maps. Students will need to use the scale at the bottom of the original

A circular sinkhole in the sinkhole plain with contours superimposed on the photograph. Contour interval is 5 feet. The sinkhole was 85 feet in diameter and led to a 5 foot deep depression in the center that acted as the drain to a bedrock fissure. Any runoff from rain that falls within the hachured contour will flow toward the center of the sinkhole and into the bedrock fissure.

topographic map to determine how far ½ mile is on the map.

Have the class reassemble after each group has determined the karst area on their maps. Display each group's map to determine variations in interpretation of the sinkhole areas. Ask the students if all of their karst zones match up with the karst zones of their fellow students. Adjust the boundaries as needed. Color in the areas with sinkholes with a dry erase marker to highlight the karst regions of the maps.

The students have just created a karst map. Maps such as these help geologists, urban planners, engineers, builders, and farmers determine important information about the place they live and work. To make an exact karst terrain map, you would have to go to the field and inspect your line of demarcation between areas with sinkholes and without sinkholes. The map produced is a simplified version that shows generally where karst can be found in the region.

Discussion Questions

Why do sinkholes form in clusters?

Why is it important to understand and predict where sinkholes will form?

Where would be a good place to build a new home?

Where would be a good place to open a landfill?

What does a sinkhole look like on a topographic map?

What hypothesis can you form about the characteristics of the bedrock in this area based on the presence of sinkholes, disappearing streams, and caves?

Where do sinkholes and caves typically form?

How could you verify this hypothesis?

What is the average depth of the sinkholes on the map?

Draw a side view (a cross-section) of a sinkhole.

Which cities on the maps are in areas that are susceptible to contamination of shallow groundwater resources?

Create A Sinkhole Density Map

Photocopy portions of the finalized Karst Map and give each student or group a portion of the total map. Instruct the students to count all of the sinkholes in each section of their map portion. Remind the students that the map symbol for sinkholes is a closed contour line with inward pointing hachure marks.

Background information about topographic maps

Topographic maps show the numbered grid formed by the U.S. Public Land Survey System (PLSS) (also called the township and range system). The PLSS divides nearly all the land in Illinois into nearly square townships, each about 6 miles on a side. The numbered grid used to designate these townships is laid out along a north-south Principal Meridian, and an east-west Base Line at right angles to the meridian. The point where the two lines cross is the zero on the grid. The first 36-square mile township north and east of this origin is designated T.1N., R.1E. Each township is divided into 36 sections each one mile on a side. The sections are numbered consecutively, starting from the northeast corner of the township as 1, and following a zig-zag pattern down the successive tiers of sections: the northernmost tier numbered from 1-6 east to west, the next tier 7-12 east-west, and so on. The center of the township's grid of sections lies at the common corner of sections 15, 16, 21 and 22.You can use this lesson to reinforce basic topographic map skills learned at an earlier time. The students will have experience using scale, township, range, section, and map symbols.

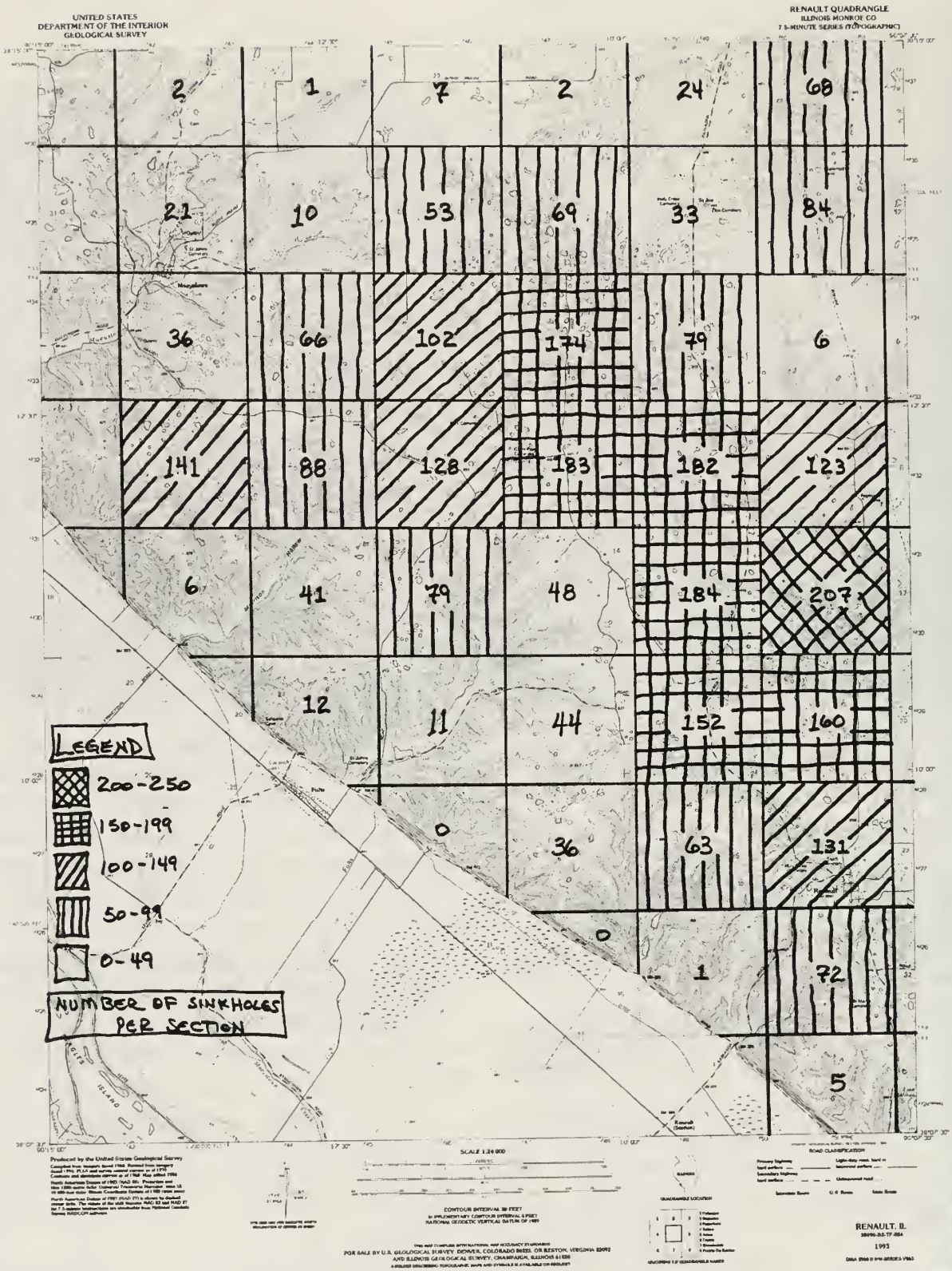
For each sinkhole, the student will select the innermost closed contour (if there is more than one) and color the entire hole in with a yellow highlighter. For example:

This is counted as one sinkhole
This is counted as two sinkholes

Count the sinkholes in each section, coloring them as they are counted. The reason for the coloring is so that you don't count the same sinkhole twice or miss any sinkholes. Record the number of sinkholes per section and go on to the next section. There will be some sinkholes that are on two or even four sections. Pick the section where the majority of the sinkhole lies and count it as being on that section. If a sinkhole appears to be half in one section and half in another, choose a consistent way to count them, such as placing the sinkhole in question in the section on the right or above. When the students have finished their individual sections have them color an overlay and attach it to the original Karst Map.

A suggested color key is provided below.

Number of sinkholes
200-250 = red
150-199 = orange
100-149 = yellow
50-99 = green
1-49 = blue


UNITED STATES
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7 5-MINUTE SERIES (TOPOGRAPHIC)
2
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1
72
5
LEGEND
200-250
150-199
100-149
50-99
0-49
NUMBER OF SINKHOLES
PER SECTION
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
RENAULT, IL
1993

Land-Use Planning in Karst Terrain

How humans use and change the land we live on is an issue for all of us to be concerned with for a safe future. What decisions are necessary to make sure everyone is happy with the way land is used? Is it possible to please everyone? This exercise is designed to introduce you to some of the factors used in land-use planning.

You will be involved in making decisions, defending your decisions, and revising your decisions for the good of your community. The information you need to make your decisions is on a series of attached maps. Your task is to look at the maps, which provide information about resources, transportation, and geology. Use information from all of the maps to find the best place for your land use needs.

Background

Conduct a discussion of how humans impact land-use and land-use decisions prior to the activity. Explain how karst presents the potential for unusual environmental problems by easy contamination of groundwater. The susceptibility to contamination of aquifers in non-carbonate bedrock sections is due to high permeability of sand and gravel deposits near the rivers. The high sensitivity in carbonate bedrock areas (karst areas) is due to the existence of direct conduits such as sinkholes and fractures in limestone bedrock, which allow runoff water to move directly into the groundwater aquifers beneath the surface. The runoff water or surface water can carry dissolved solution pesticides, fertilizers and other contaminants.

Discuss the sensitive environmental status of the area in contrast with the need of humans who live in the area. Why do people want to live there? What will happen as more people move into the area? Can we halt progress?

This exercise is a good example of the complexity scientists, lawmakers, community leaders, environmentalists, and businesses face when making environmental decisions. There are often no "right" answers to these problems. Students will learn to make decisions from a variety of perspectives and to think about problems from more than one side.

Scenario 1

You are the owner of My Town Quarry, Inc and you have a problem. The city has grown up around you and you are no longer able to quarry the limestone you need to stay in business. In order to stay in business you will have to begin quarrying in another location. You want to stay in the general area because your family lives there and your children are in school here. Moving to a new state or opening a quarry where one exists already are not options.

Based on the maps provided use the following criteria to make your decision: transportation, existing land use (farmland, quarries, etc...), potential mineral resources, and availability of your product, limestone (carbonate bedrock). Remember to consider the problem from as many perspectives as possible: economic, jobs, quality of life, and environmental impact.

When you have decided on the location for your new quarry write a short paragraph describing why, in your opinion, this location is the best one. Also, answer the following questions:

1. Which map contributed most to your decision?

2. What changes will you have to make in your business to succeed in a new location?

3. Give three reasons to support the choice for your new location.

4. Give three ways your business will be affected by the move.

5. Can you think of arguments against opening the new quarry where you have chosen?

Scenario 2

You are an official for the county waste disposal department. It is your job to find a place to locate a new landfill. The landfill must serve the entire area. Based on the maps use the following criteria to make your decision: transportation, natural areas, karst, groundwater quality, current land-use, and urban areas. Remember to consider the problem from as many perspectives as possible: economic, jobs, quality of life, and environmental impact.

1. Which map contributed most to your decision?

2. Give three reasons to support the choice for where you will place the landfill.

3. Give three ways your community will be affected by the placement of the landfill.

4. Give three arguments against building the landfill where you have chosen?

Procedure

Break the students into small groups of 2-3.

Provide each group with a set of maps and a scenario. One way to help students visualize the variety of ways land is used is to photocopy the maps provided onto overheads so the students can overlap them as they consider the problems.

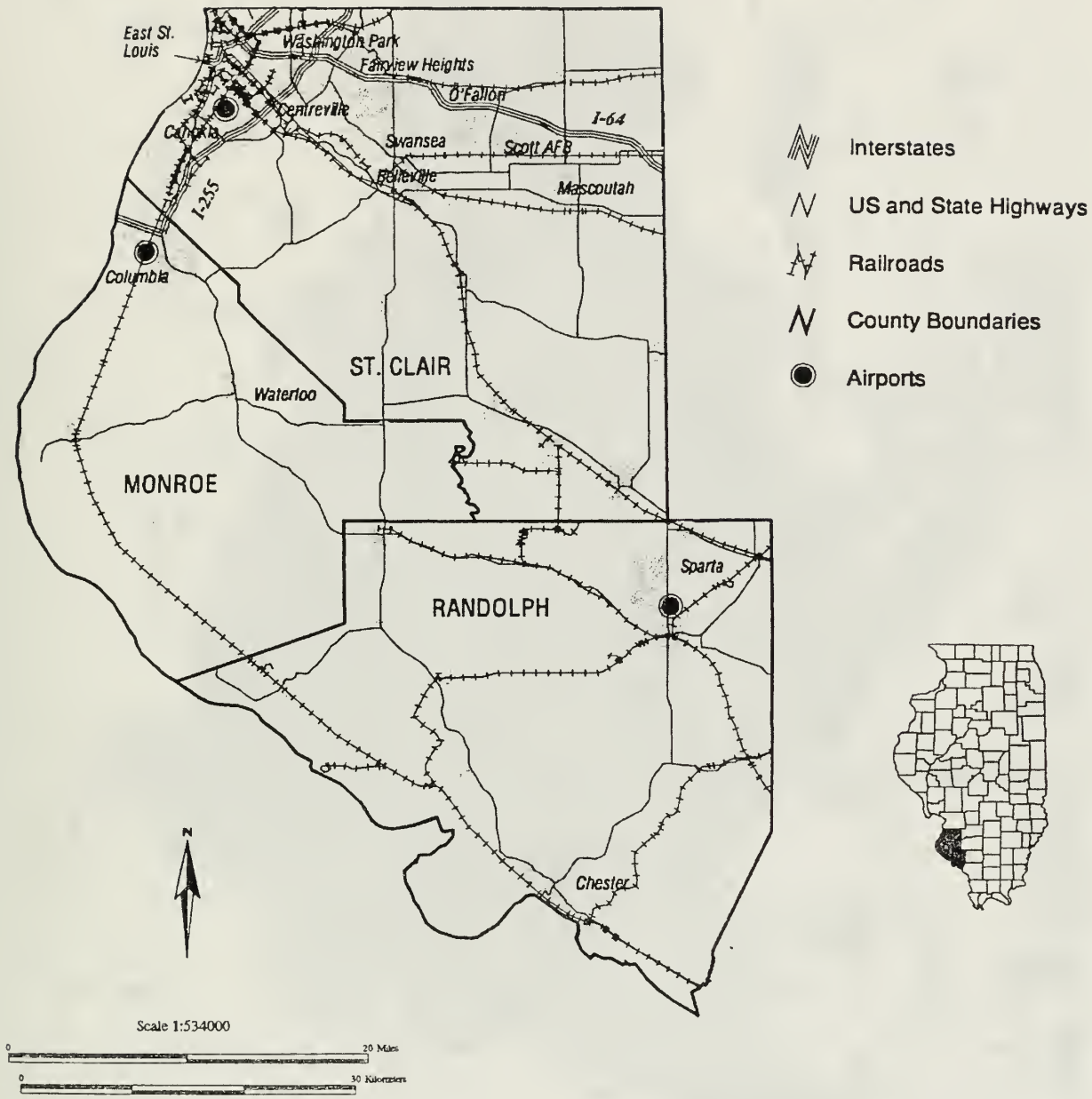
Instruct them to select an area that fits all the criteria to solve their problem.

Have the students write a paragraph, or give a presentation to the class that outlines why they chose the area they did. Suggest they include advantages and disadvantages to their location.

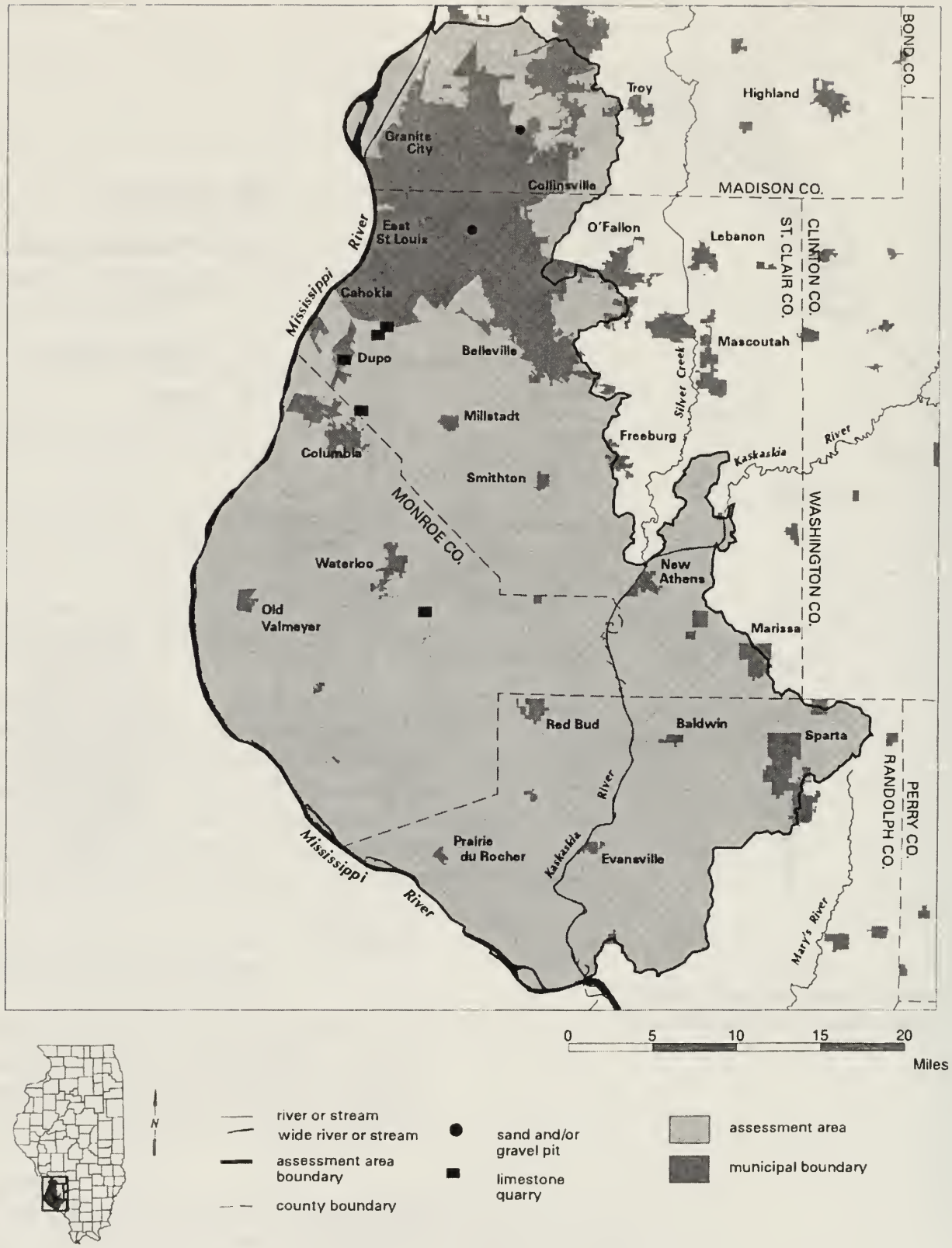
References

Critical Trends Assessment Program (CTAP), 1998. Sinkhole plain area assessment. Volume 1: Geology. Illinois Department of Natural Resources, Springfield Illinois.

Critical Trends Assessment Program (CTAP), 1998. Sinkhole plain area assessment. Volume 4: Socioeconomic profile, environmental quality, archaeological resources. Illinois Department of Natural Resources, Springfield Illinois.

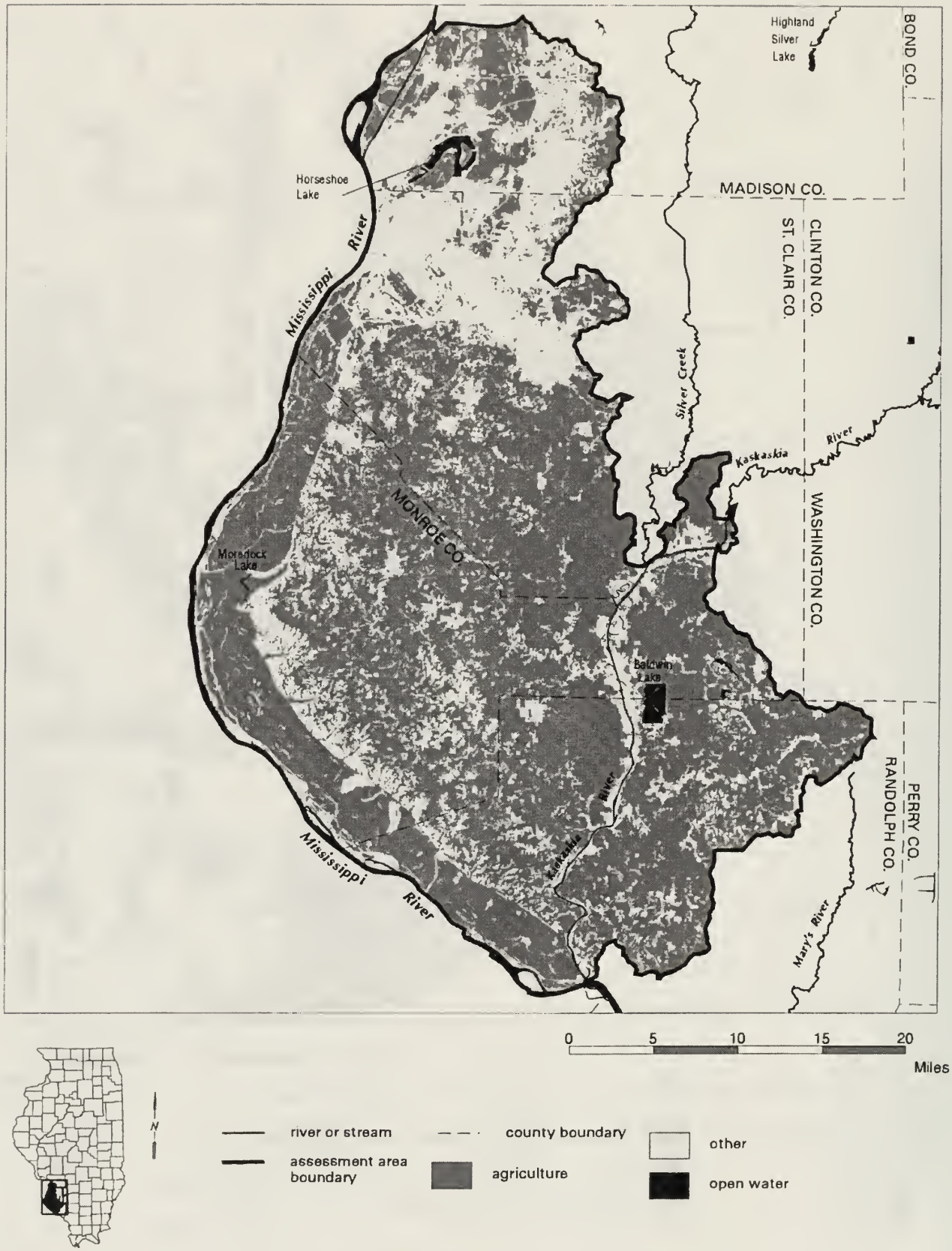


Major airports, roads and railways in
southwestern Illinois (CTAP, v.5, 1998)

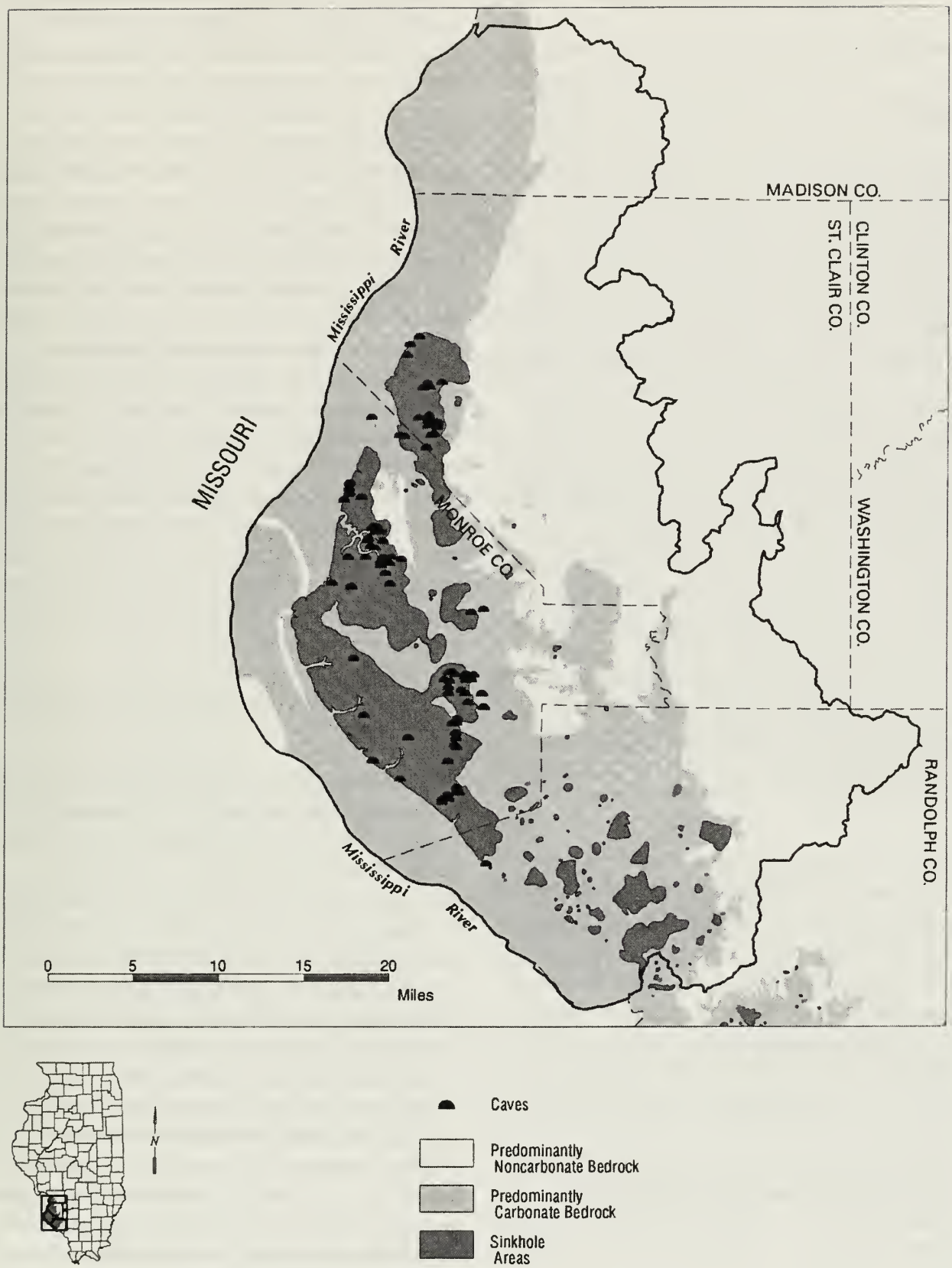


Active sand and/or gravel pits, and limestone quarries in southwestern Illinois (from CTAP, v.1, 1998).

Aquifer sensitivity to contamination by pesticide leaching (from CTAP, v.1, 1998).



Priciple lands cover of the sinkhole plain.
Agricultural lands (from CTAP, v.1, 1998)



Karst terrain of the sinkhole plain of southwestern Illinois (from CTAP, v.1, 1998).

FIELD ACTIVITIES

Geologic Mysteries Of Illinois Caverns

Geologists use a variety of problem solving skills to answer geologic questions. This section presents a series of seven geological mysteries found in Illinois Caverns (Figure 26). These geologic mysteries are designed to help you unlock the stories and histories hidden inside the features you will see in Illinois Caverns State Natural Area. For each mystery there is background information explaining the formation of the feature highlighted in the geological mystery and suggested discussion questions. There is an activity worksheet that challenges students to solve the mystery. Each mystery includes photographs and diagrams showing the evolution of particular features. Students are presented with a problem to solve: how the features they are seeing formed, why the features look the way they do, and, what is the history of the feature. They are encouraged to use their understanding of physical and chemical processes learned in the pre-field trip activities to unravel the problem and solve real-life geologic mysteries. The mysteries are presented in the order a group will encounter them, from the entrance to the main parts of the cave.

These geological mysteries model the problem solving process geologists use to explain the world around them. The Principle of Uniformitarianism, "the present is the key to the past", is often applied by geologists and other scientists when trying to unlock the mysteries of the past. We look to the processes and features we see in the present to explain what has happened in the past. Geologists also use relative time to help determine the series of events that occurred to form the features we see today. Determining which piece of the mystery happened first, second, and so on... defines the history of a feature and helps solve the mystery of its formation.

Discussion and recording of observations while in the cave are an effective way to guide students through these mysteries. Encourage students to describe what they are seeing either verbally or in notebook form. Photographs are also useful for recording observations and features while in the cave. Geologists gernally keep a notebook in which they record field notes, descriptions, and drawings of what they observe in the field. Drawing pictures of the features observed in the cave or on the surface near the cave helps students to look at the features in greater detail than they normally would. Point out to the students that small details are often the key to understanding the processes responsible for a deposit or cave formation. Encourage students to ask themselves questions such as: How and why did these features form? What was deposited or what event occurred first, second, etc.? As they seek the answers to these questions, they must carefully examine the evidence that they can observe and consider how to interpret that evidence to obtain the answers. To do this, the students must formulate hypotheses and test their validity on the basis of their observations.

The Scientific Process And Alternate Interpretations

The interpretations of the geological mysteries in this document are just that, interpretations. They are hypotheses based on scientific principles, observations, and data. A scientific investigation is an evolving entity. Scientists develop hypotheses that best fit their observations and data, and build their interpretations on the foundations laid by previous researchers. Subsequently, scientists can further test these hypotheses by making additional observations and/or using new techniques. Challenging scientific interpretations is part of the scientific process and it is expected and encouraged. A challenge involves the proposal of an alternate hypothesis supported by additional observations and data that better explains both the new observations and the original observations and data. Such activities spark scientific debate and, in this way, the science of any discipline is advanced.

We recommend that the instructor challenge the students to develop alternate hypotheses to explain the geological mysteries described herein and identify other mysteries present at the Illinois Caverns State Natural Area that they can attempt to solve. The hypotheses need to be based on basic scientific principles and known phenomena that occur in the Illinois Caverns and sinkhole plain area. Alternative hypotheses are offered for many of the mysteries. However, these are only examples and the list is by no means exhaustive. Encourage the students to use their imaginations and remind them that being wrong is part of the scientific process. Remember, too, that a scientific hypothesis may be "right" on the basis of the currently available evidence, and is only proven to be "wrong" when new evidence becomes available, or when a more general hypothesis is developed that covers both the original and subsequent observations.

Mystery 1: The Entrance

Objectives

To demonstrate the reasons for sinkhole formation in the sinkhole plain.

To examine landscape and bedrock features.

To gain experience in relating geologic processes to actual geologic features.

Background

The entrance to Illinois Caverns is a large, bowl-shaped depression in the soil called a sinkhole. The sinkhole formed when soil collapsed into the underlying crevice. Originally (immediately after its formation), the sinkhole probably had steep, near-vertical sides. Erosion created more gently sloping walls in the soil zone, and the cave stream took away the soil that fell in long ago (See Karst Terrain Information Sheet for more information).

As you descend into the cave, you walk downward through a cross-section of the soil zone, the soil-bedrock interface, and the limestone bedrock. This is an excellent view of the succession of earth materials that we walk on everyday, but cannot normally see. The bedrock appears dirty and crumbly, which is due to the unique environment near the base of the soil zone. At the soil/bedrock interface, the bedrock and bedrock crevices are subjected to harsh conditions that result in the bedrock being continually exposed to acidic soil water. The soil water dissolves the limestone as it moves downward into the cave. The acidic water and runoff (after exposure by sinkhole formation) have enlarged the entrance from its unknown original size (Figure 27) to an elongate opening that is about 70 feet in length and 10 to 15 feet wide (Figure 28).

Three main lines of evidence must be interpreted to determine how and why the entrance of Illinois Caverns formed in its present location: the presence of karst features, the bedrock type, and the fracture patterns in the bedrock. The entrance is a sinkhole, and karst features, especially sinkholes, are common in the area. The bedrock is bedded limestone and is very pure calcium carbonate, which rapidly dissolves in rainwater, snowmelt, and soil water, relative to most other rock types (e.g., shale). The bedrock fractures in this area tend to run east-west, the same direction as the entrance to Illinois Caverns.

Suggested Discussion Questions

1) How would early visitors have entered the cave before the stairs were installed?

2) Would a large hole in the ground, such as the cave entrance, be a danger to large animals? What would happen if they fell into the cave and there were no stairs to climb out?

3) Why didn't the early explorers find a pile of bones at the bottom of the sinkhole on the cave floor?

4) Is the bowl-shaped depression at the entrance a feature that formed in the soil or in the bedrock?

Figure 27. *An excavated sinkhole revealed a long crevice in the exposed bedrock that leads to a somewhat wider crevice. The crevice led down, about 15 feet, into a small cave about 1 foot high and 2 feet wide through which rainwater and snow melt flowed.*

Figure 28. *A troglobite's view of the entrance to Illinois Caverns. The entrance was originally a fracture or crevice that was enlarged by the dissolving action of infiltrating soil water and surface runoff (rain and snow melt).*

5) Why is the passage through the bedrock at the entrance of Illinois Caverns long and narrow?

Answer Sheet

Suggested Discussion Questions

1) How would early visitors have entered the cave before the stairs were installed?

A: The early land owners entered on ladders. Previous explorers (if any) may have used ropes.

2) Would a large hole in the ground, such as the cave entrance, be a danger to large animals? What would happen if they fell into the cave and there were no stairs to climb out?

A: The funnel-shaped sinkhole and the deep crevice at the bottom would serve as a trap for animals that wandered too close to the crevice. Once in the cave, they probably couldn't escape.

3) Why didn't the early explorers find a pile of bones at the bottom of the sinkhole on the cave floor?

A: The cave stream floods frequently and the remains of any carcasses would be washed away.

4) Is the bowl-shaped depression at the entrance a feature that formed in the soil or in the bedrock?

A: The bowl-shaped depression formed as a sinkhole in the soil overlying bedrock. When the crevice was large enough, soil fell or was washed in and a sinkhole formed above it.

5) Why is the passage through the bedrock at the entrance of Illinois Caverns long and narrow?

A: The opening in bedrock was originally a near-vertical fracture in bedrock that, over thousands to tens of thousands of years of soil water and surface water flowing through, enlarged to its present width. Most bedrock crevices in the sinkhole plain are only about 6 inches to a foot wide.

The Entrance: Student Activity

The Setting
The entrance to Illinois Caverns is an exceptionally large opening at the bottomof a roughly circular depression.

The Mystery
What is the entrance to the cave and how did it form?

Procedure
Answer the following questions in order to solve the Geologic Mystery of the Entrance to Illinois Caverns. This mystery is divided into two parts.

Question 1:
What type of landscape feature is the entrance to Illinois Caverns on which the wooden stairs were built?

Clues:
Examine the terrain of the State Natural Area and determine if you see any other features (in the area of the entrance) that resemble the entrance to Illinois Caverns. Draw and label a picture of the entrance (side and map views) and how they relate to the cave passage below.

Question 2:
Describe the shape of the opening in the bedrock that leads to the cave. What type of rock is the bedrock? Did this opening form by natural processes or is it man made?

Clues:
1) Examine the walls of the rock at the entrance and look for evidence of an excavation or cleanly-broken rock surfaces. Determine if the rock surface is smooth or irregular and if it shows signs of dissolving along bedding planes. A smooth, cleanly broken rock surface would indicate a man-made opening. An irregular rock surface with exaggerated bedding planes would indicate an opening enlarged by the dissolution of rock by inflowing, naturally-acidic rainwater and soil water.

Side view

Map view

Answer Sheet

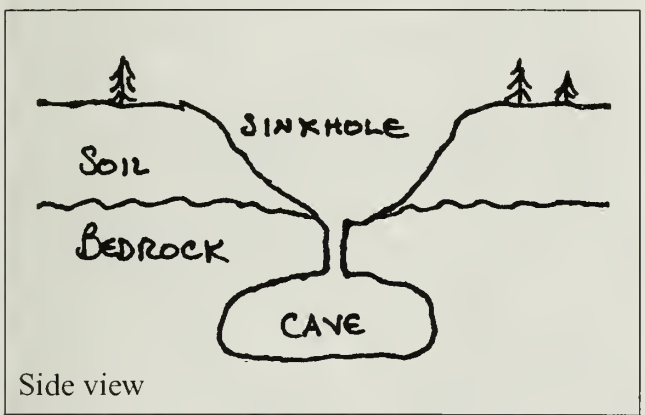
Question 1:
What type of landscape feature is the entrance to Illinois Caverns on which the wooden stairs were built?

A: The feature on which the wooden stairs were built is a sinkhole.

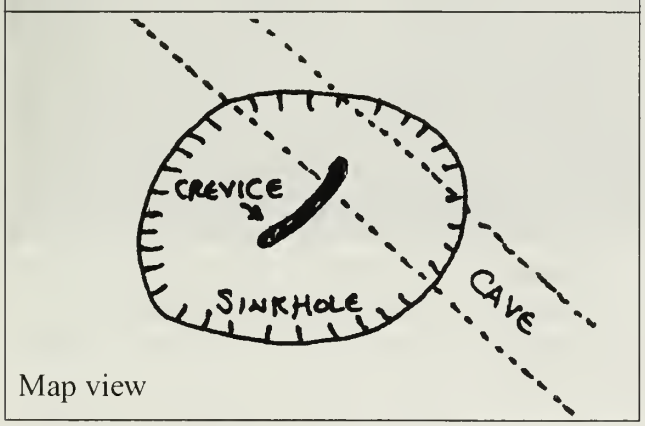
Clues:
Examine the terrain of the State Natural Area and determine if you see any other features (in the area of the entrance) that resembles the entrance to Illinois Caverns. Draw and label a picture of the entrance (side and map views) and how they relate to the cave passage below.

Question 2:
Describe the shape of the opening in bedrock that leads to the cave. What type of rock is the bedrock? Did this opening form by natural processes or is it man made?

A: The opening in bedrock is a long, narrow crevice about 70 feet long and about 10 to 15 feet wide.



Side view



Map view

A: Bedrock is made of limestone that dissolves as rainwater and soil water flow through it.

A: The ragged nature of the rock surfaces and the exaggerated bedding planes show that the opening to the cave is natural. It was dissolved away by rainwater and soil water.

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Mystery 2: Human Visitation

Objectives
To learn about the environmental consequences of visiting a cave and the long-term effects of vandalism on its natural treasures.

To examine and recognize differences between naturally-occurring features and man-made features.

Background
Because there have been visitors to Illinois Caverns for well over 100 years, and because of the repeated attempts to commercialize the cave, the cave holds much evidence of human visitation. That is, the cave is no longer in pristine conditions and many features have been modified since they saw their first human visitors. It is important to be aware of the existence of these features because they could lead to misinterpretation of the natural mechanisms responsible for the formation and evolution of the cave.

The most obvious modification is seen at the entrance. Wooden stairs lead down along the shallow margin of the sinkhole that leads to the beginning of the bedrock surface. Once at the bedrock, the very steep stairs become concrete and lead downward through a large crevice in the bedrock. Near the base of the stairs is a large iron gate that once graced the Waterloo jail, and below that is a fenced, concrete landing that lies on the cave floor. Stepping from the landing, you may notice that the cave floor, especially near the stream, is covered with large flat slabs of limestone that are carefully laid and have been

there for so long that they look natural (Figure 29).

Figure 29. *That part of the cave near the bottom of the stairs has been built up and covered with flagstones by previous owners to make it easier for visitors to walk in the cave. The flagstone walkways stop at the first waterfall.*

Walking downstream into the main part of the cave, you may occasionally see a metal clip attached to the ceiling with a nail. These clips were used to hold strings of electric lights during mid-20th century attempts to commercialize the cave. Major alterations include the flagstones and metal grates that guide you through the early part of the cave. This relatively elaborate trail ends just after the first waterfall and you cannot avoid walking in the stream from this point onward. However, signs of human visitation do not end here, but continue throughout the cave.

Foot traffic has worn shallow trenches in the fine sediment that lies adjacent to the cave stream and on routes to upper passages (e.g., Capitol Dome). Rocks and speleothems can also show wear from visitors touching and rubbing them as they pass. For example, the stalagmite at the end of the upper passages in the Canyon Passage, accessible via ladders, shows a considerable amount of smoothing from people holding on to it as they descend or ascend the aluminum ladder.

Vandalism is a very serious problem in Illinois Caverns. The cave is blessed with abundant speleothems that tempt many visitors. You will notice that many stalactites have been broken off throughout the cave and only their white stumps are visible in the ceiling (Figure 30). This is unfortunate because it takes an extremely long time for speleothems to regrow to their previous size (hundreds to thousands of years). Writing of names and dates on the ceiling and walls is also tempting for some visitors and such graffiti can be seen on the ceilings of the Canyon Passage and the Lunch Room (Figure 31). The Site Interpreter must routinely scrub the rocks to remove new graffiti from the cave.

Trash is also a problem in this and other caves. Visitors carelessly drop batteries and broken flashlights, soda and beer cans, cigarettes,

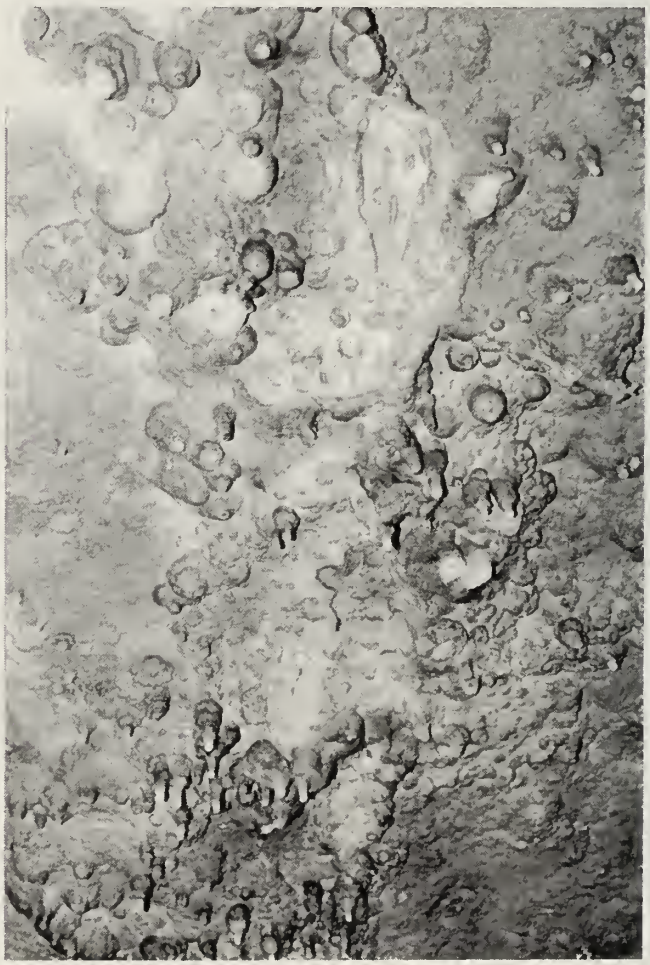


Figure 30. *Vandalism denuded this field of stalactites in a manner similar to clear cutting of a forest. Some of the stalactites are beginning to regrow and others remain lifeless stumps.*

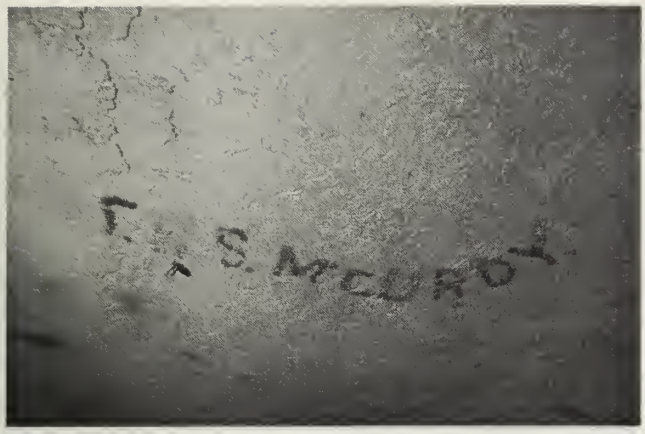


Figure 31. *Graffiti are common in Illinois Caverns. In this instance, there is a name written on the ceiling of the cave with the soot from a carbide lamp. Carbide lamps, which produce bright, open acetylene gas flames, were once commonly used by cavers and miners. If an early explorer wrote his or her name in the cave around the year 1900 or so, that would be consid historical signature, but still a graffito that defaces the cave.*

matches, food and candy wrappers, etc. all though the cave.

Human land usage affects the ecosystem of Illinois Caverns in less visible ways too. There is a loss of biodiversity within the cave stream and the cave itself. The abundance of some species of invertebrates that live in the cave stream has decreased in parts of the cave. The reasons for the loss of some species of invertebrates is not known, but may be due to groundwater contamination from septic systems, livestock, and/or row crop agriculture. In addition, the number and types of bats that use Illinois Caverns for a roosting place is probably affected by heavy visitation to the cave. These effects can be found by studying the cave environment, the cave stream, and the processes that form caves in the area.

Suggested Discussion Questions

1) What clues of human visitation did you unconsciously and unavoidably leave in the cave?
2) What clues of human visitation left by someone before can easily be removed (by you) from the cave that would help maintain its natural beauty?

Answer Sheet

Suggested Discussion Questions

1) What clues of human visitation did you unconsciously and unavoidably leave in the cave?

A: I probably left some footprints on the soft sediment that may deepen some of the trenches along the path into the cave. I also contributed to the smoothing of the stalagmite used as a handhold while descending the aluminum ladder in the Canyon Passage. In addition, I may have unknowingly stepped on some of the aquatic cave biota in the stream.

2) What clues of human visitation left by someone before can easily be removed (by you) from the cave that would help maintain its natural beauty?

A: Trash of all sorts, including spent batteries, beverage cans and bottles, cigarette butts, broken flashlights.

Human Visitation: Student Activities

The Setting

The entrance and throughout Illinois Caverns.

The Mystery

What clues are there at the entrance and within the cave that tell that there have been many other visitors here before you?

Procedure

Work through this mystery in groups and with the assistance of your teacher, and answer the following questions:

Questions 1:

Look at the entrance, and the walls, the floor, and the ceiling of the cave.

What clues, aside from the stairs at the entrance, tell you that you are not the first person to visit Illinois Caverns?

Look for evidence of human visitation throughout your tour of the cave and make a list of the evidence in your notebook.

Clues

1) The floor of the cave at the bottom of the entrance, as you step off of the stairs and for a short distance into the cave up to the first waterfall is unusually flat for a cave. Examine it closely and determine why it is so flat.

2) Crossing the cave stream can be difficult if you want you feet to stay dry. In addition, climbing can be tricky. Look at these areas for clues of human visitation.

3) Illinois Caverns was a commercial cave for a short period in the early 1900s and again in the 1940s. Lights were installed for some distance into the cave. Look at the ceiling to find evidence of lighting in the cave as you walk downstream.

4) Examine speleothems (stalactites and stalagmites) for evidence of vandalism and other signs of human visitation.

5) As you walk into the cave, you are in places forced to walk through shallow trenches in the soil. Examine these and determine how they were formed.

6) Look at the ceiling and walls of the cave, especially in the Canyon Passage and Lunch Room, for any other evidence of human visitation. Describe the signs of visitation you see.

Answer Sheet

Question 1:

Look at the entrance, and the walls, the floor, and the ceiling of the cave.

What clues, outside of the stairs at the entrance, tell you that you are not the first person to visit Illinois Caverns?

Look for evidence of human visitation throughout your tour of the cave and make a list of evidence in your notebook.

A: The floor is leveled with flagstones for easier walking. The ceiling still has a few metal hooks that were used for lighting when this was a commercial cave. The walls and ceiling have graffitti written on them (usually peoples names and the dates they visited the cave). Metal bridges and ladders have been installed for crossing streams and climbing. Stalactites have been broken off by earlier visitor and their white stumps show glisten against the brown rock. Trash is occasionally found along the trail.

Mystery 3: Age Of Stalactites

Objectives

To demonstrate the rate of speleothem (stalactite) growth in Illinois Caverns.

To understand the consequences of removing a speleothem from a cave.

To demonstrate the connection between time and geologic processes.

Background

Vandalized stalactites provide valuable clues to understanding stalactite formation in Illinois Caverns. A forest of stalactite stumps lies just downstream from the cave entrance (on the right and up onto a soil bank just before the cave narrows) (Figure 32). A close look at the stalactites reveals two things: 1) stalactites have concentric banding similar to tree stumps, and 2) small, soda straw stalactites are growing on the stumps of some of the larger stalactites.

Stalactites begin forming as soda straws and typically grow where groundwater seeps from the cave ceiling through small fractures. These initial stalactites are similar in size, geometry, and appearance to soda fountain straws, including a hole down the center. Water flows down the center of the soda straw, when it reaches the end of the straw it degasses carbon dioxide, causing calcite to precipitate. As the soda straw stalactites continue to evolve, water flowing across the outside of the stalactite precipitates calcite one layer at a time, thickening and lengthening the stalactite. The growth history of stalactites is recorded in rings, similar to the growth rings in trees. The outermost ring is the youngest and the innermost ring is the oldest. Often the original soda straw hole in the center is still visible on the broken end. The concentric rings may represent annual growth. The various sizes of crystals in the rings may provide information about water flow rates. Various coloration of the rings may reflect differences in the amount of organic acids leached from soil above the cave and can indicate change in seasons. That is, the darker colors may represent more organic compounds in the drip water during the summer growing season,

Figure 32. *A view of the broken stalactite field and the new growth (soda straws). The largest stumps are about one inch in diameter where they are attached to the ceiling. Water droplets may be seen at the tips of several of the newly forming stalactites. Each new stalactite is about one half to one inch in length (as measured from the base of the broken stalactite to the tip).*

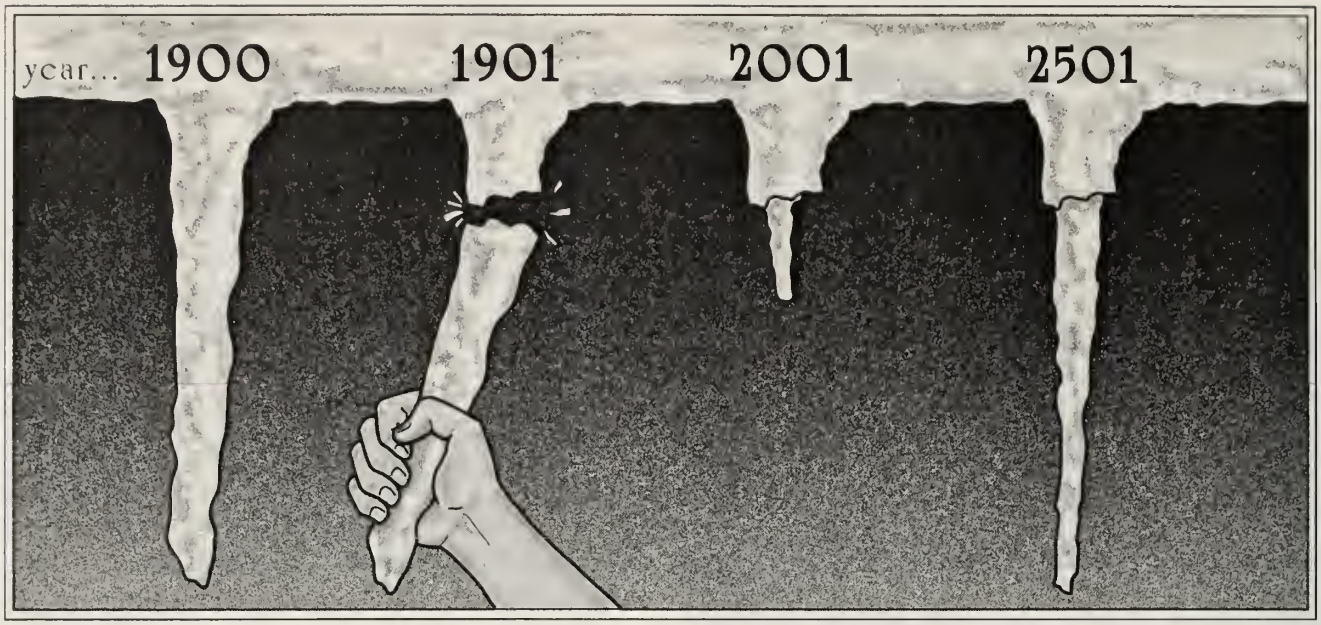


Figure 33. *Stalactites in Illinois Caverns appear to grow at a rate of about 1 inch every 100 years. However, this rate may be faster or slower depending on the volume of water flowing through the ceiling, as well as other factors. At that rate, if a stalactite was broken off in the year 1901, then the regrowth of the stalactite would be about an inch in length in 2001 and close to its original length in 2501. However, the looks of the stalactite would be modified .*

and the lighter colors may represent less organic compounds during the winter (similar to the color differences between strong and weak tea).

Historical accounts show that people started visiting the cave on a regular basis about 100 years ago. This forest of small, broken stalactite stumps near the cave entrance probably represented the first stalactites visitors saw upon entering the cave. Their small size and delicate nature made them tempting souvenirs for the early visitors. Thus, it is likely that all of these stalactites were broken off about 100 years ago. By knowing how long ago the stalactites were broken and measuring the length of the current soda straw stalactites forming, we can estimate how long it takes for stalactites to grow (Figure 33). The soda straw stalactites here have grown about 1 inch in the last 100 years or 0.01 inches/year. Similar growth rates have been found in other caves. It is important to remember that growth rate can vary over time and depends on many factors including: 1) flow rate of water streaming down the stalactite, and 2) how nearly saturated the water is with the mineral calcite.

Suggested Discussion Questions

1) How old do you think some of the largest stalactites in the cave (e.g., in the Canyon Passage just past the Ladders) might be, based on the length of time it took for the tiny ones to regrow (about one inch in 100 years).

2) Why do some passages have abundant stalactites and others have none?

Answer Sheet

Suggested Discussion Questions

1) How old do you think some of the largest stalactites in the cave (e.g., in the Canyon Passage just past the Ladders) might be, based on the length of time it took for the tiny ones to regrow (about one inch in 100 years)?

A: Some of these large stalactites in the Canyon Passage appear to be 10 feet (120 inches) long. At a growth rate of one inch per 100 years, they would be about 12,000 years old.

2) Why do some passages have abundant stalactites and others have none?

A: Stalactites form where there are fractures that intersect the cave and allow groundwater in the bedrock to seep into the cave. Where there are no fractures to provide groundwater access to the cave, there are no stalactites.

Age of Stalactites: Student Activity

The Setting

Stalactites are occasionally broken off and removed from the cave by vandals. What remains is a stump similar to a tree stump. The stalactites may continue to grow and form secondary growths on the stumps.

The Mystery

Find a group of broken stalactites showing new growth after they were broken off. Assuming the stalactites were broken off about 100 years ago, determine their growth rate and what they will look like in 100, 500 and 1000 years?

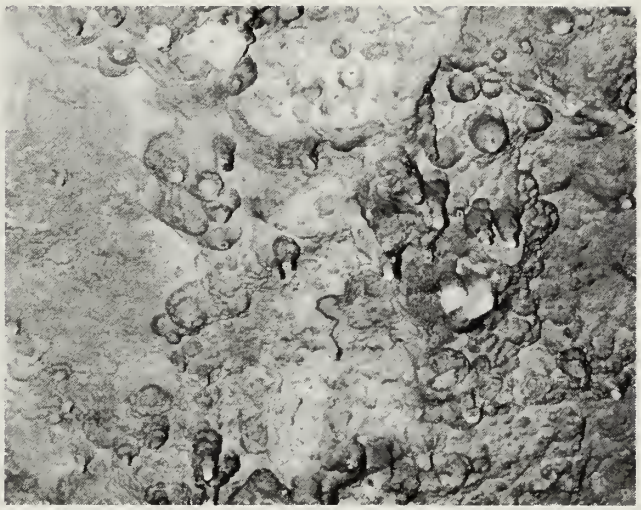
Procedure

Work through this mystery in groups and with the assistance of your teacher. Locate broken stalactites with new growth and measure the length of the new stalactite with a ruler (be careful not to touch the stalactites). Answer the following questions:

Question 1:

If you assume the stalactite was broken off about 100 years ago and the secondary growth is about 1 inch, what is the growth rate? Calculate the growth rate as inches per year for:

1) 1 year.
2) 100 years.
3) 500 years.
4) 1000 years.

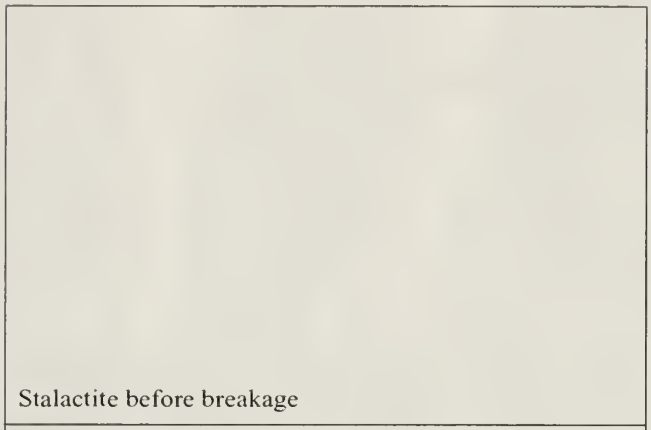


Clues:

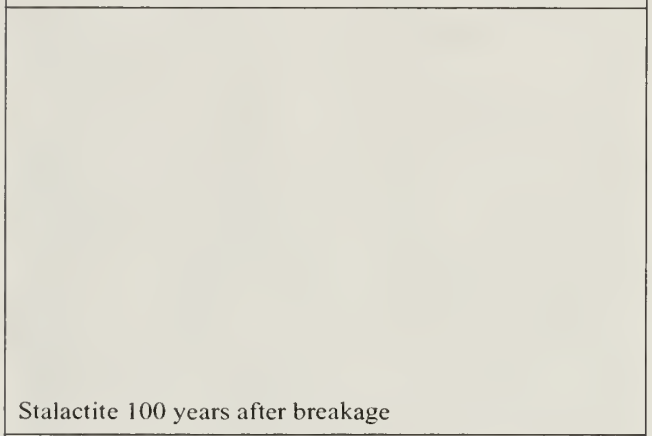
Growth rate is measured as length/time. For example, if a stalactite was broken off 100 years ago and the new stalactite is 3 inches long, the growth rate would be 3 inches in 100 years or 1 inch/33 years. This means that the annual growth rate of the new stalactite is 0.03 inches/year.

Predict the growth of the newly-forming stalactites you observed on the stalactite stumps. Assuming a growth rate of one inch per 100 years, draw the stalactite 1) as it appeared before it was broken off, 2) the newly growing stalactite 100 years after it was broken (how they appear today), 3) 500 years after breakage, and 4) 1000 years after breakage. Scale your drawings to fit in the boxes and indicate the length of your stalactites for each period. Note: To determine what the broken stalactite looked like, examine stalactites of about the same diameter (at the point

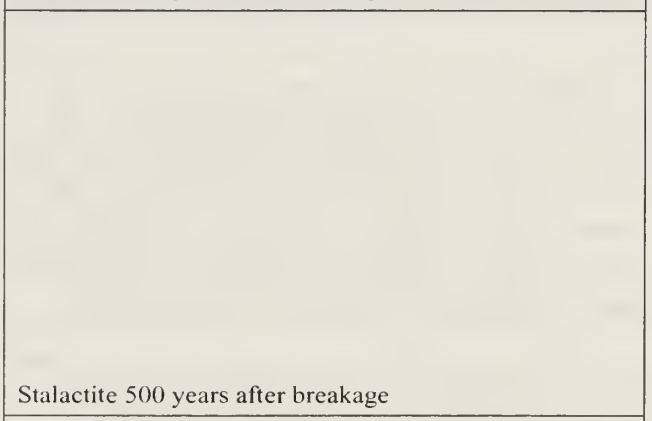
where they are connected to the ceiling) and estimate or measure their length. Be careful not to touch the stalactites as you measure them.



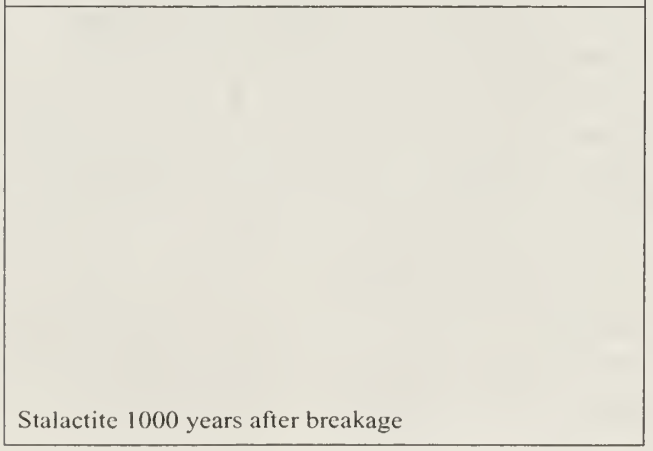
Stalactite before breakage



Stalactite 100 years after breakage



Stalactite 500 years after breakage



Stalactite 1000 years after breakage

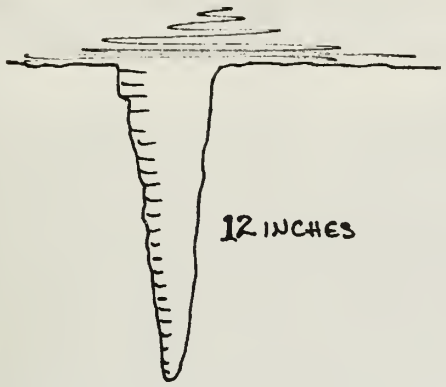
Answer Sheet

Question 1:

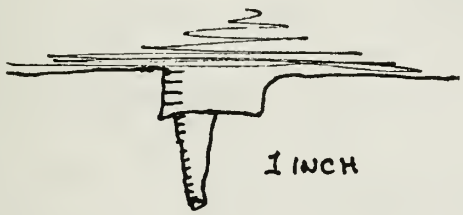
If you assume the stalactite was broken off about 100 years ago and the secondary growth is about 1 inch, what is its growth rate? Calculate its growth rate as inches per years for:

1) 1 year.	Answer - 0.01 inches
2) 100 years.	Answer - 1 inch
3) 500 years.	Answer - 5 inches
4) 1000 years.	Answer - 10 inches

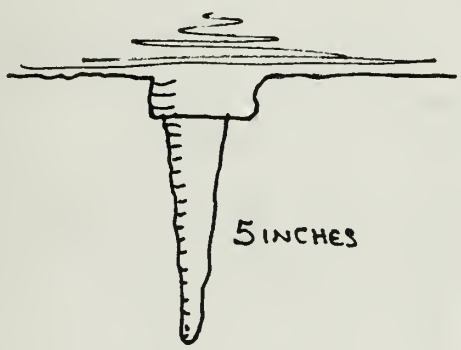
Answer: Predict the growth of the newly-forming stalactites you observed on the stalactite stumps. Assuming a growth rate of one inch per 100 years, draw the stalactite 1) as it appeared before it was broken off, 2) the newly growing stalactite 100 years after it was broken (how they appear today), 3) 500 years after breakage, and 4) 1000 years after breakage. Scale your drawings to fit in the boxes and indicate the length of your stalactites for each period. Note: To determine what the broken stalactite looked like, examine stalactites of about the same diameter (at the point where it is connected to the ceiling) and estimate their length.



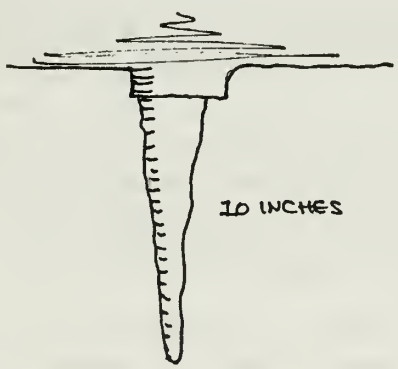
Stalactite before breakage



Stalactite 100 years after breakage



Stalactite 500 years after breakage



Stalactite 1000 years after breakage

Mystery 4: How Chimneys And Speleothems Form In The Same Environment

Objectives

To learn about how water flows through bedrock via fractures and bedding planes before entering the cave and how long that process takes.

To learn that two different geologic processes can occur in the same environment as a result of seemingly minor changes, such as the flow paths of water.

Background

The Lunch Room contains numerous stalactites and stalagmites, which form as groundwater saturated with the mineral calcite seeps into the cave through fractures along bedding planes. These speleothems are examples of depositional features. Amidst the speleothems of the Lunch Room is a chimney that extends about 30 feet upward into the limestone ceiling. Chimneys are features that form when groundwater that is under-saturated with the mineral calcite dissolves limestone. Chimneys are an example of dissolution features (Figure 34).

This side-by-side occurrence of deposition and dissolution features presents a mystery. Namely, how is it possible to have water seeping into the cave that is so saturated with the mineral calcite that it is precipitating calcite stalactites and stalagmites, while just a few feet away, water is seeping into the cave that is so under-saturated with calcite that it is dissolving the bedrock and forming a large chimney? The answer to this geologic mystery is that the two very different types of water are entering the cave along two different paths. Prior to entering the cave, water can follow two different flow paths near the place where the soil and bedrock meet, called the soil-bedrock interface. Both paths pass through the soil zone, but once they meet the bedrock surface, they split (Figure 35).

One flow path takes the water on a relatively slow journey through fractures and bedding

Figure 34. *This chimney (above) is located in the Lunch Room just to the right and behind the stalagmites, stalactites and flowstone (below). The close proximity of inflowing water capable of precipitating calcite and dissolving limestone suggests the existence of different flow paths for soil water seeping into the cave from above.*

planes in the limestone bedrock. Because this water moves slowly through the bedrock, it becomes saturated with calcite. Water that takes the slow journey into the cave is saturated with calcite and when it degasses carbon dioxide as it seeps into the cave, it forms speleothems.

The other flow path takes the soil water on a short trip through the bedrock and into the cave through a relatively large fracture. This water that enters the cave quickly has not been in contact with the limestone bedrock long enough to become saturated with the mineral calcite. The water is still acidic and dissolves limestone as it enters the cave. Water that enters the cave after a short journey acts like a natural drilling tool that dissolves its way into the cave and creates a chimney. The water flows down the face of the inside of the chimney with a minimum of splashing. There is little opportunity for the water to degas, become less acidic and deposit calcite as it flows through the chimney.

Farther into Illinois Caverns is Chimney Passage, where one of the chimneys contains flowstone. Timing is important to explain this geologic mystery. The chimney must have formed first in order for flowstone to deposit on the inside surface of the chimney. It is likely that the flow path of the water entering the cave here changed at some point during the history of the cave. Originally, the water took a short journey into the cave and flowed directly from the soil zone into the cave ceiling. Now the water is taking the slower journey into the cave that involves interaction with bedrock before it enters the cave ceiling. This feature is a good example of how geologic processes can evolve through time.

Suggested Discussion Questions

1) How can two distinct geologic features (chimneys and speleothems), requiring two different types of inflowing water (one capable of dissolving limestone, and one capable of depositing calcite), form immediately adjacent to each other?

2) What mineral is being dissolved at the bedrock-soil interface and in the chimney, and is being deposited as speleothems?

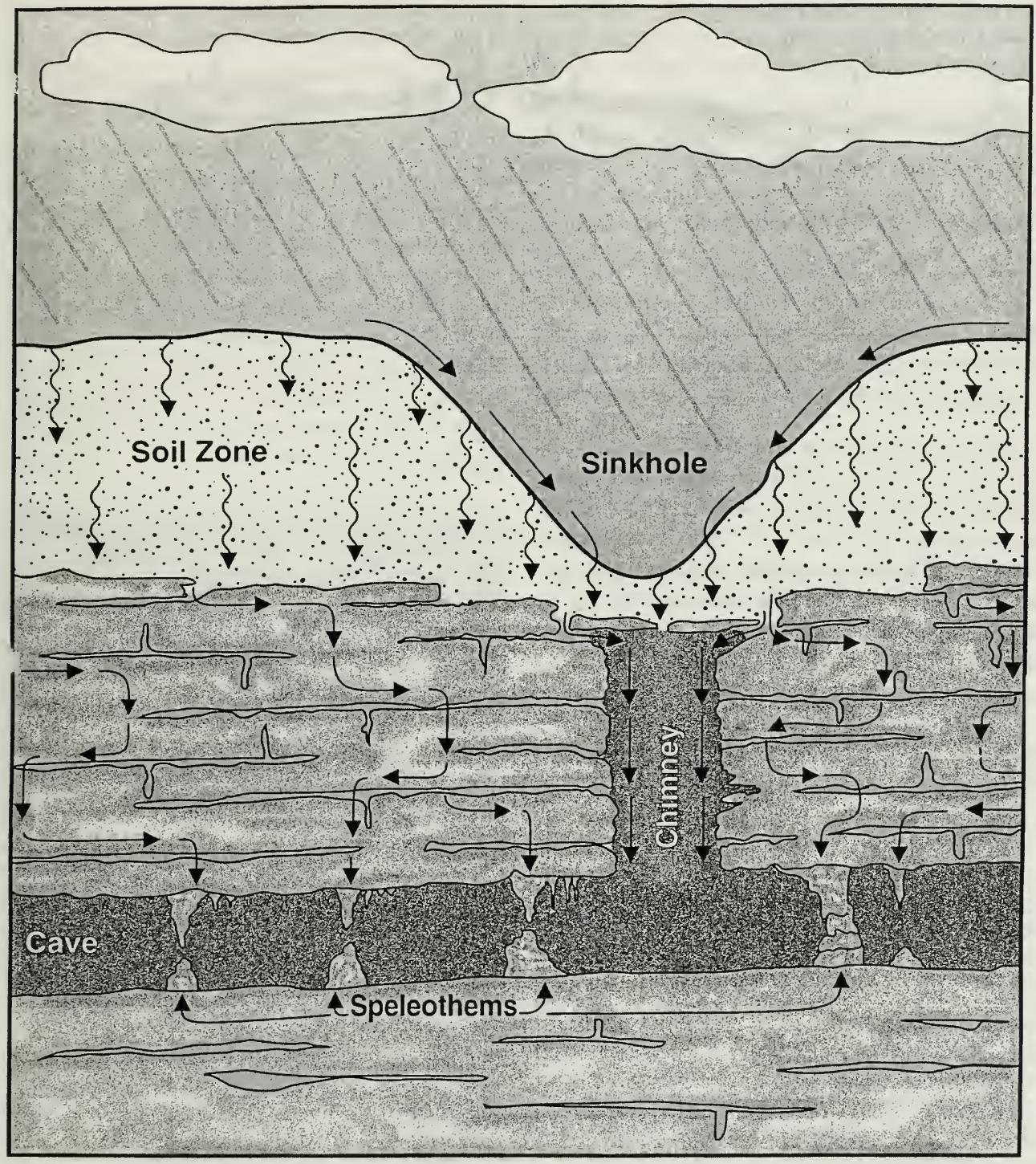


Figure 35. *Chimneys and speleothems may form in the same vicinity owing to the differences in the chemical composition of water seeping into the cave. If the water seeping through the soil zone intersects a relatively thick sequence of limestone or dolomite, the water will be saturated with the mineral calcite be the time it intersects the cave below. If the soil water seeps into a crevice that takes it rapidly into the cave, then the water will be capable of dissolving the mineral calcite. The results will be an enlargement of the fracture leading to the cave and a chimney eventually may form.*

3) How does water seeping into a cave change from dissolving limestone to depositing calcite in the same location, but at different times?

Answer Sheet

Suggested Discussion Questions

1) How can two distinct geologic features (chimneys and speleothems), requiring two different types of inflowing water (one capable of dissolving limestone, and one capable of depositing calcite), form immediately adjacent to each other?

A: The two inflowing waters take two different flow paths through the fractures and along bedding planes in the bedrock limestone. One enters the cave in a short amount of time (hours) and is able to dissolve limestone and form features such as chimneys. The other water enters the cave after several days or more flowing through bedrock and is now saturated with calcite and capable of depositing speleothems in the cave.

2) What mineral is being dissolved at the bedrock-soil interface and in the chimney, and is being deposited as speleothems?

A: Limestone and speleothems (in Illinois Caverns) are both made up primarily of the relatively easily dissolved mineral calcite.

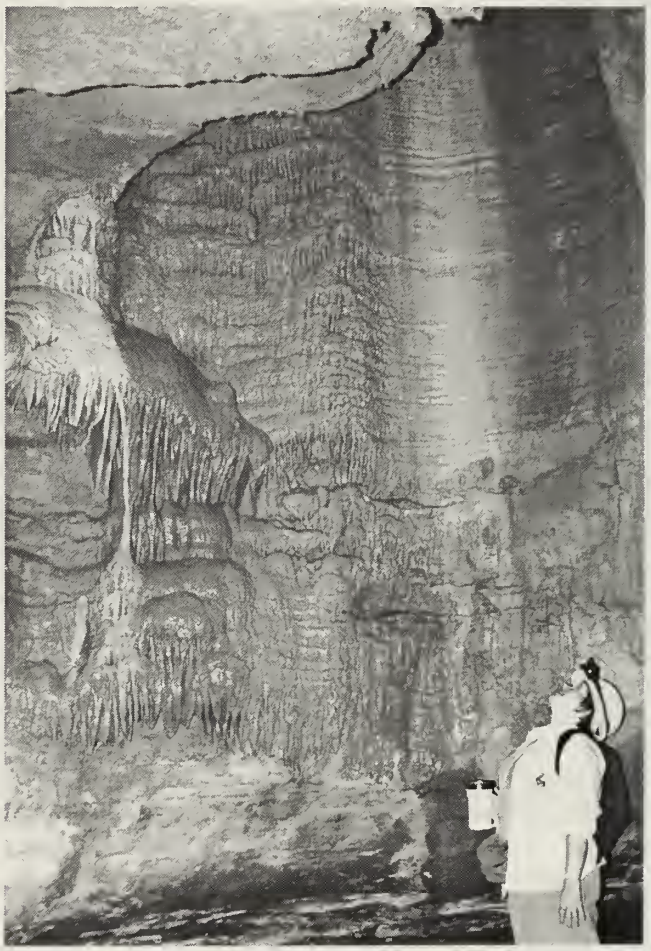
3) How does water seeping into a cave change from dissolving limestone to depositing calcite in the same location, but at different times?

A: Flow paths for water through bedrock can change with time. Short flow paths can plug up and send the water on a longer flow path; the converse is also possible.

How Chimneys and Speleothems Form in the Same Environment: Student Activity

Setting

The Lunch Room is a well-decorated part of Illinois Caverns with abundant stalactites, stalagmites, and flowstone. It also contains two spectacular chimneys, all in a relatively small area. The presence of speleothems indicates that water, saturated with the mineral calcite, is seeping into the area and depositing its mineral load as it enters the cave. The presence of chimneys indicates that water capable of dissolving calcite, is flowing into the same area and creating vertical shafts. Chimneys in caves of the sinkhole plain typically form beneath sinkholes.



The Mystery

How is it possible to have these two different types of water seeping into a small area at the same time?

Procedure

Work through this mystery in groups and with the assistance of your teacher, and answer the following questions:

Question 1:

We are going to explore the effect the length of time it takes for water to move through the bedrock has on the amount of calcite the water is capable of dissolving. If soil water or rainwater seeping through bedrock enters a vertical fracture that takes it directly into the cave in an hour or less, what would happen to the sides of the vertical fracture?

Question 2:

What if it takes a week for the soil water to wind its way through a maze of bedrock fractures before entering a fracture that takes it into the cave? Will this water be capable of dissolving any more limestone (calcite) or will it deposit calcite?

Clues:

1) If a piece of calcite were dropped into soil water or rainwater, their slightly acidic nature would begin to attack and dissolve the calcite. However, the amount of acid within these waters is limited and it will be used up over time. Soil water and rainwater flowing through bedrock and entering the cave within a day or less will still be able to dissolve limestone (mostly calcite). However, these water lose their ability to dissolve calcite after several days flowing through bedrock.

2) Try an experiment: Take a small (pea-size) piece of limestone or calcite and place it in a small container. Add about an ounce of vinegar (a weak acid), and watch for fizzing or bubbles forming as the limestone or calcite dissolves in the vinegar. Observe when the bubbling is the strongest (after several minutes, after one hour, after three hours). The gas that is forming is carbon dioxide. This experiment will help you discover what happens when soil water is in contact with bedrock for short and long periods of time.

Question 3:

Does the amount of vinegar you add to the limestone make a difference as to how long it fizzes? For example, if the fizzing stops and you add more vinegar, what happens? How does this help explain the process of chimney formation?

Question 4:

In what way would a sinkhole control the volume of water (as runoff) entering a relatively small area of bedrock during a major rainfall event? Describe the effect.

Clues:

Draw a sinkhole looking down from above (map view) and from the side (side view) as though you could see through the soil and consider the following questions:

Where does runoff from rainfall go when it is in an area with no sinkhole? Does it all enter the ground or does some of it enter the soil and most of it flow off to a stream?

Map view

Side view

Which has more water focused on a smaller area of bedrock: A sinkhole or an area where water enters the soil and fractured bedrock more uniformly and where most of the rainfall runs off?

Answer Sheet

Question 1:
We are going to explore the effect the length of time it takes for water to move through the bedrock has on the amount of calcite the water is capable of dissolving. If soil water or rainwater seeping through bedrock enters a vertical fracture that takes it directly into the cave in an hour or less, what would happen to the sides of the vertical fracture?

A: The water would dissolve limestone along its flow path down the fracture and the fracture would widen.

Question 2:
What if it takes a week for the soil water to wind its way through a maze of bedrock fractures before entering a fracture that takes it into the cave? Will this water be capable of dissolving any more limestone (calcite) or will it deposit calcite?

A: By the time the water gets into the cave, it will be saturated with calcite and would only be capable of depositing calcite in the cave.

Question 3:
Does the amount of vinegar you add to the limestone make a difference as to how long it fizzes? For example, if the fizzing stops and you add more vinegar, what happens? How does this help explain the process of chimney formation?

A: The more vinegar you add, the longer the fizzing continues.

A: If you add more vinegar after the fizzing stops, the fizzing will begin again.

A: The more water flowing through the fractures, the more limestone it will dissolve. The fracture will become wider and wider and eventually form a chimney

Question 4:
In what way would a sinkhole control the volume of water (as runoff) entering a relatively small area of bedrock during a major rainfall event? Describe the effect.

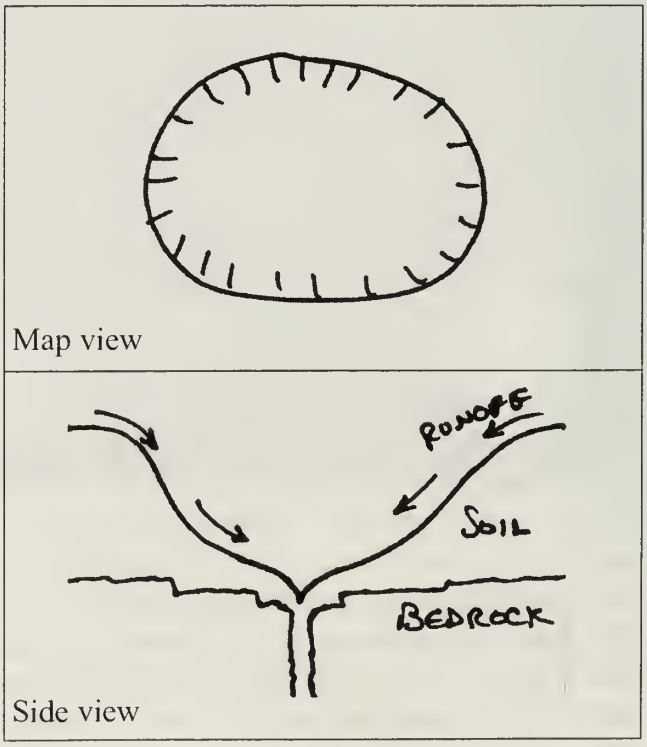
A: The sinkhole would act as a funnel and direct a relatively large volume of water to a very small area of bedrock. The more water, the more limestone that would be dissolved.

Clues:

Draw a sinkhole looking down from above and from the side as though you could see through the soil and consider the following questions:

Where does runoff from rainfall go when it is in an area with no sinkhole? Does it all enter the ground or does some of it enter the soil and most of it flow off to a stream?

A: Some rainfall enters the soil and most of it flows off to a stream.



Which has more water focused on a smaller area of bedrock: A sinkhole or an area where water enters the soil and fractured bedrock more uniformly and where most of the rainfall runs off?

A: The sinkhole can focus more water to a smaller area. The fracture or crevice at the bottom of the sinkhole should be widened at a faster rate than ones receiving water spread out over a larger area.

Mystery 5: Tilted Speleothem

Objectives

To recognize trends in naturally-occurring features in the cave and notice variances to these features.

To learn about erosion and the consequences to things that get placed or deposited on erodable materials.

Background

Under normal conditions, speleothems grow vertically, unless they form as flowstone on a preexisting slope. However, some of the columns in Illinois Caverns are tilted at an angle very far from vertical (Figure 36). It is a geologic mystery how these columns came to be at an angle. Geologists look at similar features for clues to how these non-vertical speleothems formed. Looking at columns forming in the present, we know that columns grow vertically when a stalagmite and stalactite join. We can deduce that the non-vertical columns originally formed vertically and were somehow moved after formation to their present position. The force that moved the speleothems is almost certainly gravity.

The large column, located just before the Mushroom Passage, initially formed on a sediment pile that washed into the cave during a large flood or series of floods. Some time after the formation of the column, the sediment that supported it was eroded away, probably by the cave stream. The column became unstable and broke away from the ceiling due to its great weight (approximately 20 tons) and slumped toward the stream. The column fell toward the stream, which indicates that there was nothing supporting the column in that direction. Following its collapse, additional flowstone was deposited on the slope and surrounded the base of the column, stabilizing it in its present position and keeping it from collapsing further (Figure 37). It is important to note that not all tilted speleothems formed precisely in this manner (Figure 38).

Suggested Discussion Questions

1) What type of speleothem are you looking at?

2) What is the angle of the tilted speleothem and how could you measure that angle from a distance (or from a photograph)?

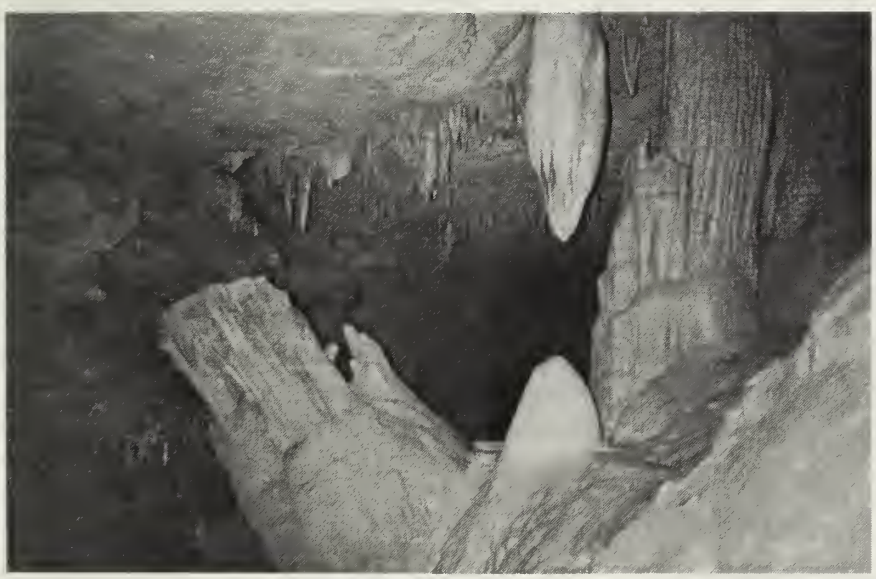


Figure 36. *A view of the tilted speleothems (left) looking downstream just after the T-Junction. A similar-looking column is seen to the right, and a stalactite and stalagmite pair are visible behind these speleothems. These speleothems are located on a slope covered with flowstone. The flowstone is covering fine-grained sediment (originally mud deposited by the cave stream tens of thousands of years ago) that originally created the slope.*

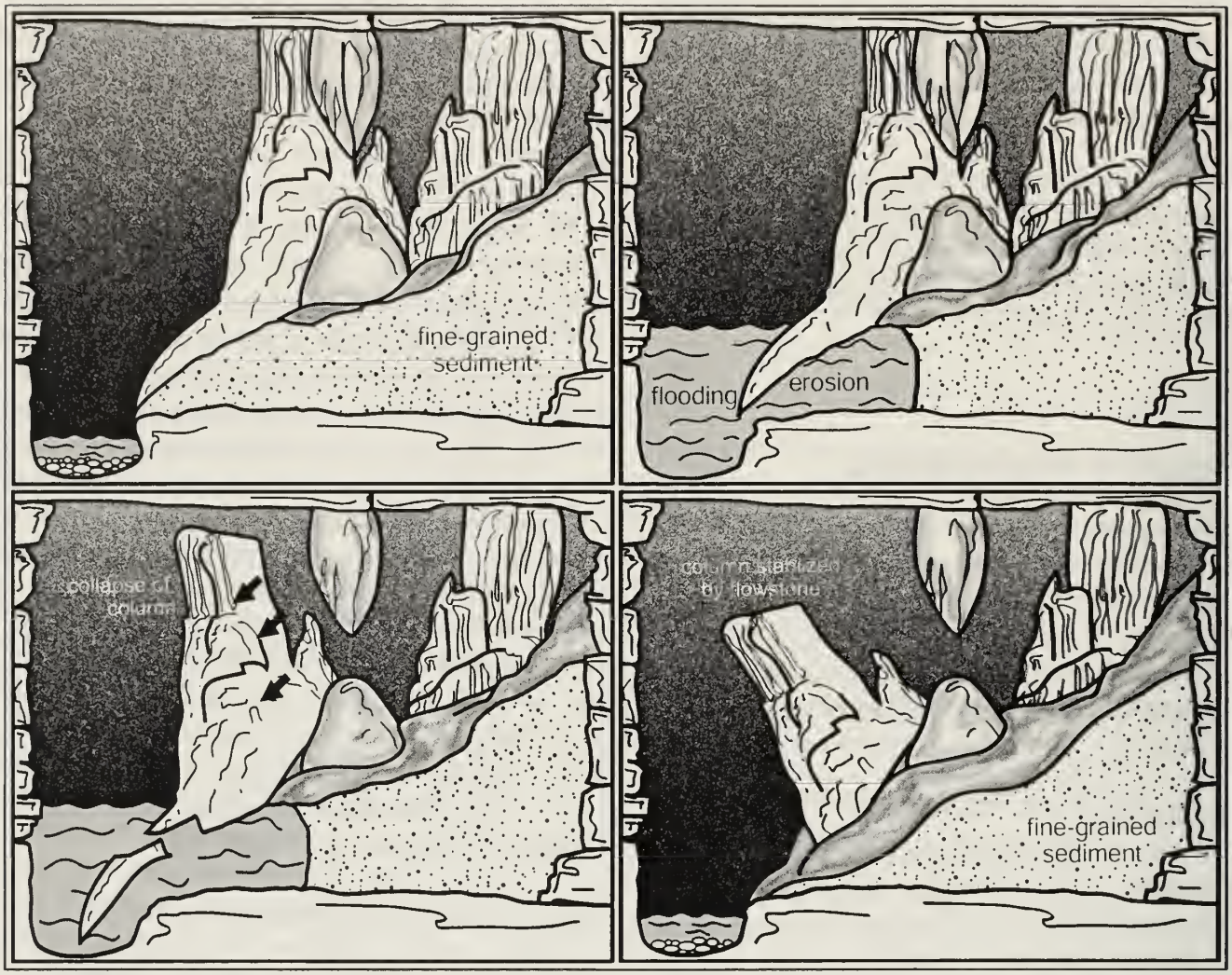


Figure 37. *The tilted speleothem is actually a column that formed on fine-grained sediments that was, at some point, partially eroded by flooding. The weight of the column and lack of support cause the column to break away from the ceiling and topple toward the stream. It came to rest at an angle and was later stabilized by flowstone.*

3) Did the speleothem form at an angle, or did it get shifted/tilted into its present position after it was deposited?

Answer Sheet

Suggested Discussion Questions

1) What type of speleothem are you looking at?

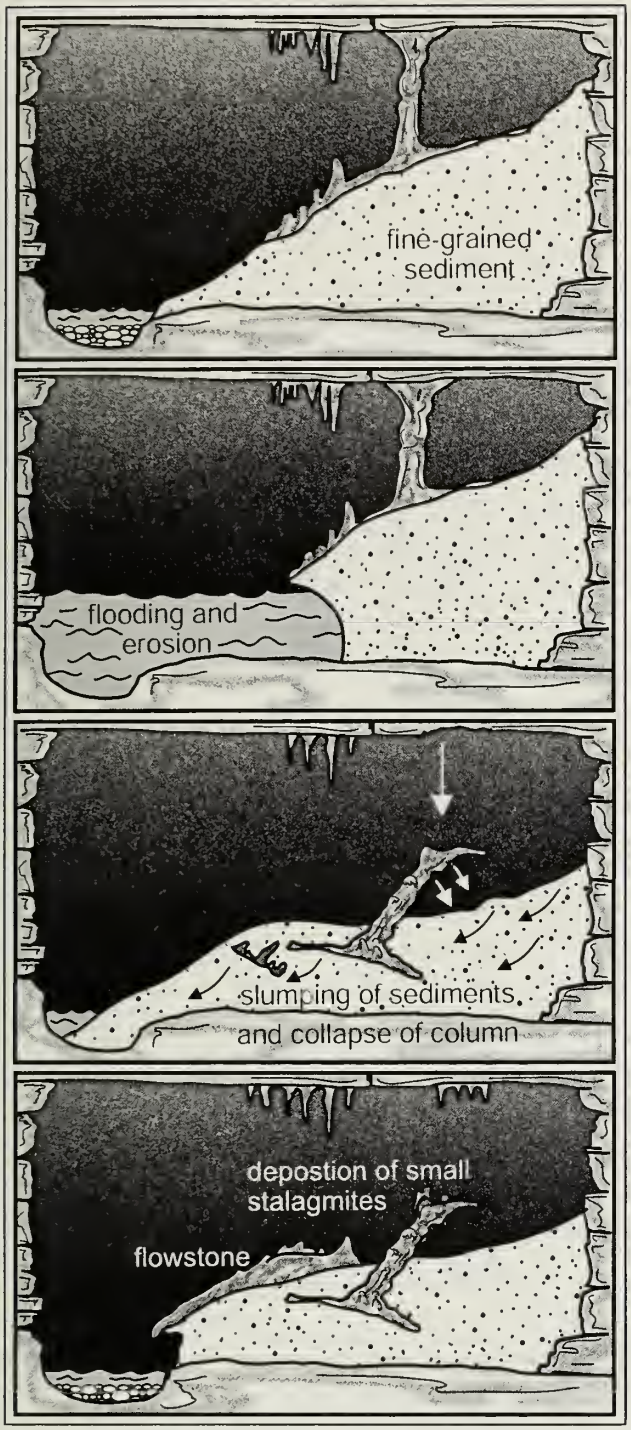
A: The speleothem is a column.

2) What is the angle of the tilted speleothem and how could you measure that angle from a distance (or from a photograph)?

A: The angle is about 35 degrees from vertical as measured with a protractor on a photograph. It is possible to measure this angle in the cave by holding a protractor up at a distance from the speleothem and approximating the angle.

3) Did the speleothem form at an angle, or did it get shifted/tilted into its present position after it was deposited?

A: The speleothem, a column, formed in a vertical manner. Erosion of the sediment on which the speleothem grew caused it to break away from the ceiling and partially fall over in the direction of the cave stream.



Tilted Speleothem: Student Activity

The Settings

There are many speleothems in Illinois Caverns that appear to be tilted from their normal vertical position. One of the largest and most impressive is located just downstream from the T-Junction.

The Mystery

What type of speleothem is this and what sequence of events could have led up to the present positionof the speleothem?

Procedure

Work through this mystery in groups and with the assistance of your teacher, and answer the following questions:

Question 1:

What type of speleothem is this and what adjacent speleothem does it most look like? Is this speleothem a:

1) Stalactite?
2) Stalagmite?
3) Column?

Question 2:

Examine the speleothem from a distance. Is its top rounded or flat? Given what you know about the shapes of stalagmites and columns, what can you determine by examining the shape of its top?

Figure 38. *The Dragon is another example of a tilted speleothem. The Dragon probably formed in a similar manner as the tilted speleothem in Mushroom Passage. The head and neck of the dragon were a column that broke away from the ceiling. However, the Dragon column is embedded in sediment and leans away from the stream. Deciphering the clues to the formation of the Dragon is more complicated than the column in the Mushroom Passage. One possible interpretation is that the cave stream undercut the sediment the column is presently sitting on. The undercutting caused the entire slope to slump towards the stream. As the sediment collapsed toward the stream, it incorporated the column and pulled it along by the base. After the column collapsed, groundwater continued to drip on the broken column from the ceiling and formed small stalagmites on its "head" and "back". These small stalagmites now appear as spikes on the back and head of a dragon.*

Question 3:
What do you think caused the speleothem to collapse?

Clues:

1) Look at the material on which the speleothems grew. Before it was covered with flowstone, it was a slope of dried sediment or mud deposited by the cave stream. Look to see if the sediment is still there. What process could have removed it?

2) The cave stream originally deposited the mud, and the stream is also capable of eroding or washing away the now dried mud during a flood. Answer the following questions:

a) If some of the sediment supporting the speleothem were washed away during a flood (called undercutting), what would happen to the speleothem?

b) What role do you think the flowstone played in stabilizing the tilted speleothem after its partial collapse?

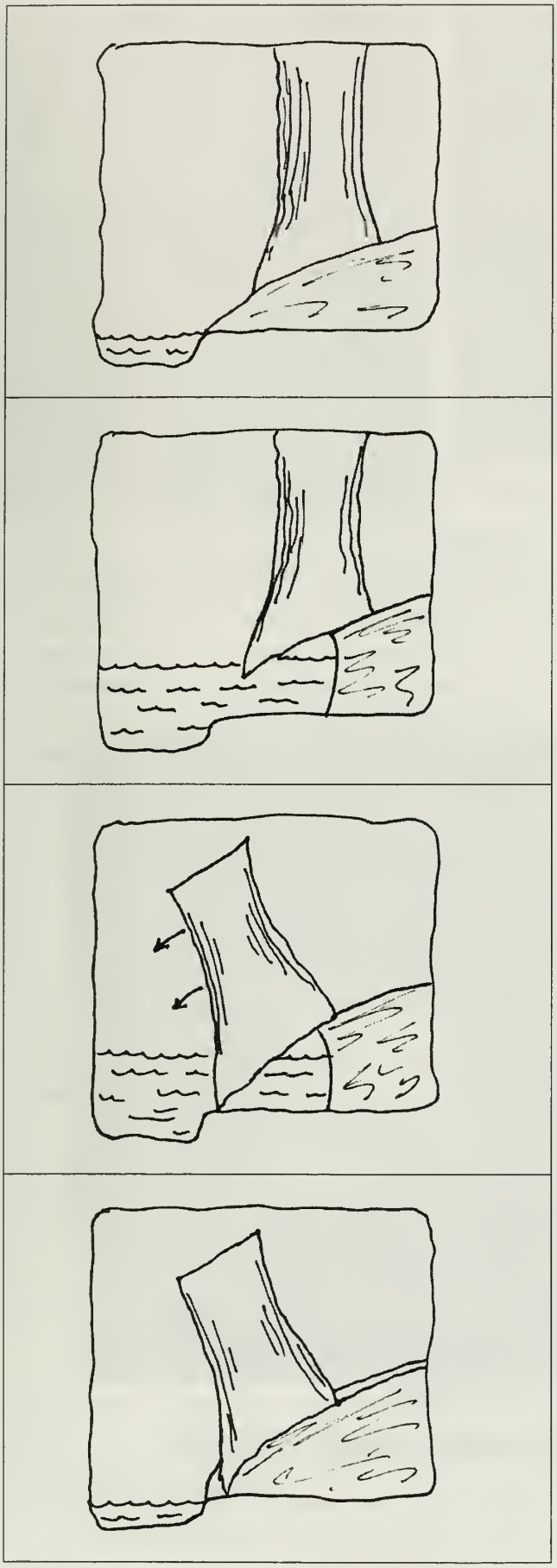
Draw four pictures to illustrate the sequence of events that created the Tilted Speleothem formation. The four drawings should show 1) the speleothem as it appeared prior to collapsing, 2) the erosion and undercutting of mud beneath the speleothem, 3) the collapse, and 4) the speleothem as it appears today.

Answer Sheet

Question 1:
What type of speleothem is this and what adjacent speleothem does it most look like? Is this speleothem a:

1) Stalactite?
2) Stalagmite?
3) Column?

A: The speleothem looks most like the column.



Question 2:
Examine the speleothem from a distance. Is its top rounded or flat? Given what you know about the shapes of stalagmites and columns, what can you determine by examining the shape of its top?

A: The top is flat. Because stalagmites have rounded tops, this must be a column that somehow broke away from the ceiling.

Question 3:
What do you think caused the speleothem to collapse?

A: Because the column is leaning toward the cave stream, and because it originally formed on sediment, it is probable that stream flooding eroded the sediment to the point where the great weight of the column caused it to break away from the ceiling and collapse toward the stream.

Answer: Draw four pictures to illustrate the sequence of events that created the Tilted Speleothem formation. The four drawings should show

1) the speleothem as it appeared prior to collapsing,
2) the erosion and undercutting of mud beneath the speleothem, 3) the collapse, and 4) the speleothem as it appears today.

Mystery 6: Mushroom Passage

Objectives

To understand how environmental change can control the formation and shapes of speleothems.

To learn that features within the cave, such as the stream level, have varied over time and such variations are recorded by things such as speleothems.

Background

The Mushroom Passage contains several speleothems that extend outward from the cave walls. The cap-like tops, flat bottoms, and mottled textures of these features make them look very much like giant mushrooms (Figures 39 and 40).

The mushroom-like features are flowstone that was deposited by calcite-saturated groundwater seeping from the walls of the cave. Groundwater that has taken weeks to months to reach the cave contains a lot of carbon dioxide gas (CO_2). Dissolved CO_2 makes the groundwater acidic. The acidic groundwater dissolves calcite, the main mineral in limestone, as it moves through fractures in the limestone bedrock. The groundwater will dissolve as much calcite as it can until the water becomes saturated with calcite and can't hold any more (it is limited by the amount of dissolved CO_2). When this saturated water enters the cave, it begins to lose carbon dioxide because the cave environment has less CO_2 in the air than the water entering the cave. The groundwater releases CO_2 to equalize the gas pressure. When the carbon dioxide is released, upon entering the cave, the water can no longer hold all of the dissolved calcite it is carrying and some of the calcite precipitates out of the solution.

In the case of the mushroom-like features, the water seeps along the cave walls and flows downward toward the cave stream. Eventually, the flowstone grows down to the water's edge, but it cannot extend farther than the surface of the cave stream. The flowstone stops growing because the steam dilutes the calcite-depositing water so that it no longer precipitates calcite. Essentially, the calcite-depositing water was washed away. Flowstone continues to grow layer upon layer down to the water's surface creating a rounded apron and flat bottom, which resembles the cap of a mushroom (Figure 41). These features are far above the level of the cave stream we see today. This is a clue that conditions in the cave have changed and the stream level has dropped since the mushroom-features formed. Recent research by the ISGS suggests that the drop in the cave stream may have been in response to a regional lowering of the water table during the Pleistocene Epoch. The drier climatic conditions, in turn, dried up the source of water forming the speleothems. Thus, when the water level dropped, the mushrooms stopped growing.

There is at least one example of a mushroom that is growing today. It is located on the left side of the passage, just after Cascade Canyon as you walk downstream; it is characterized by a black manganese oxide stripe down its center. A few mushroom-shaped features continued to form either as the stream level dropped or after. A good example of this is Rock Falls which has stalactites that formed along the edges of the mushroom cap after the water level dropped.

Suggested Discussion Questions

1) Why do the mushroom-shaped features in Mushroom Passage have such flat bottoms?

2) If the mushrooms formed on something that later eroded, what evidence would you look for to determine what the missing material was?

3) If the mushrooms grew out over stream water, why are the bottoms of the mushrooms elevated so far above the present level of the stream?

Answer Sheet

Suggested Discussion Questions

1) Why do the mushroom-shaped features in Mushroom Passage have such flat bottoms?

Figure 39. *Flowstone deposits of the Mushroom Passage grew out over the cave stream when its water level was much higher. The flowstone formed features that, with mottling from the precipitation of different minerals such as manganese oxides, look very much like their namesake (left).*

Figure 40. *A mushroom-shaped speleothem growing today is located just past Cascade Canyon on the left side of the passage as you walk downstream. Note that the flowstone is growing out over the stream. It is possible to place your hand under the flowstone and feel its flat bottom right at water level. The black stripe is manganese oxide that precipitated on the flowstone.*

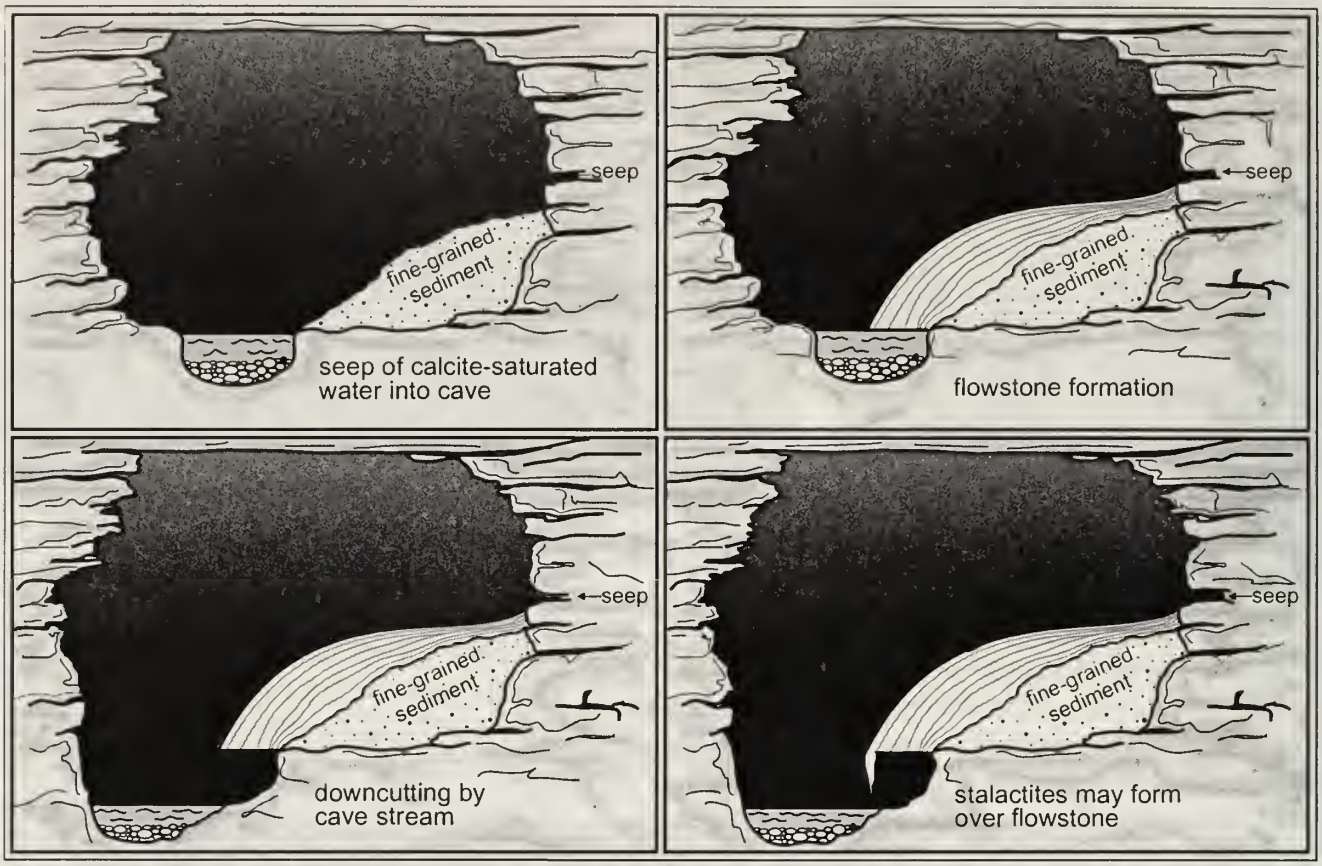


Figure 41. *"Mushrooms" are formed when groundwater saturated with the mineral calcite seeps into the cave through the wall and flows down either a sloping rock surface or fine-grained sediment. The flowstone accumulates to form a layered rock mass that drapes over the material on which it grew. If the groundwater ends up flowing onto the surface of a cave stream, then it is washed away and doesn't deposit any more materials. The result is a flat-bottomed speleothem growing out over the surface of the stream. Years later when the seepage has stopped and the stream is lower or has a lower position in the cave, the flowstone can resemble a mushroom.*

A: They grew out either over sediment that was later eroded or over the cave stream when it was at a higher elevation.

2) If the mushrooms formed on something that later eroded, what evidence would you look for to determine what the missing material was?

A: I would look under several mushrooms to see if there was sediment or gravel embedded in its bottom. It there wasn't anything still there, then water would be a better choice.

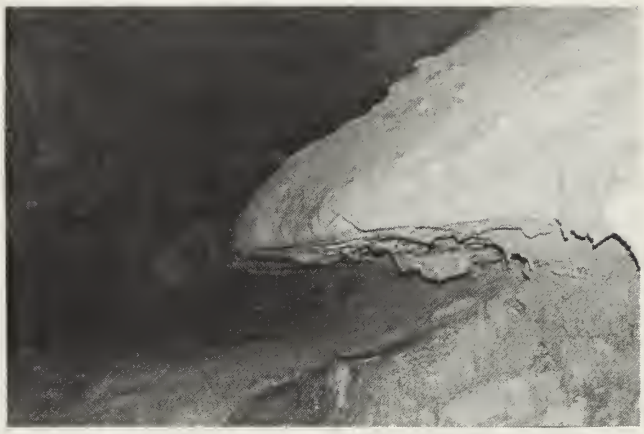
3) If the mushrooms grew out over stream water, why are the bottoms of the mushrooms elevated so far above the present level of the stream?

A: Stream valleys, even in caves, are subject to erosion and deepening. Another possibility is that the mushrooms formed during a wetter time in the past when the water in the cave stream was much deeper than it is now.

Mushroom Passage: Student Activity

The Setting

The "mushrooms" of the Mushroom Passage are flat-bottomed speleothems that extend out from the walls. Looking beneath the mushroom, you can see banding that represents layer upon layer of flowstone. The oldest flowstone is closest to the wall and the youngest is farthest from the wall.



The Mystery

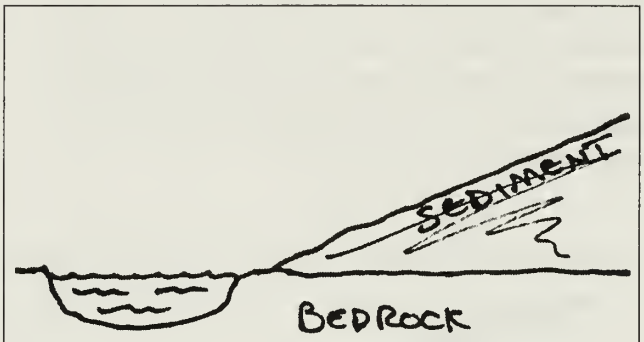
How did the mushrooms of the Mushroom Passage form?

Procedure

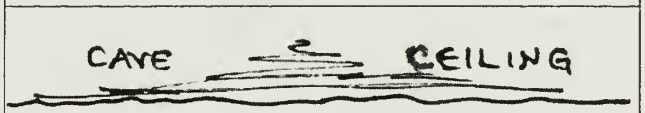
Work through this mystery in groups and with the assistance of your teacher, and answer the following questions:

Question 1:
How did the mushrooms form suspended over the cave floor?

Clues:
1) Examine other flowstone in the cave and in other photographs. How does flowstone form and where is it normally found? (Hint: Refer back to Information Section on Speleothems).
2) Examine and compare flowstone that formed on a slope with a speleothem that formed from dripping water. Describe how their shapes are different and/or draw pictures.



Speleothem that formed on a slope



Speleothem that formed from dripping water

Question 2:
If the mushrooms grew out on top of some material or liquid that is no longer there or that is now at a lower elevation, then what could have been there and now is gone or is now at a lower elevation in the cave?

Clues:
1) Examine the underside of a mushroom and determine whether it is flat or irregular. Does it contain any remnants of the materials on which it grew.

2) Consider what type of materials would leave no visible trace and list them.

3) Examine other mushroom-like features growing in the cave today (there is one just downstream from Cascade Canyon) and compare them with those of the mushroom passage that formed in the past.

Question 3:
If the mushrooms grew on the top of the stream, then why is the stream much lower in elevation today?

Clues:

1) Wetter periods during the Pleistocene Glacial Epoch could have raised the water level for many thousands of years.

2) Erosion by the cave stream could cause it to "dig" itself deeper into the cave floor, thereby lowering the water level.

Draw four pictures that show the sequence of events in the growth of a "mushroom". The pictures should show 1) the mud slope, 2) the formation of flowstone on top of the slope, 3) the mushroom growing out over the cave stream when the water level was higher, and 4) the mushroom as it looks today.

Answer Sheet

Question 1:
How did the mushrooms form suspended over the cave floor?

A: The mushrooms apparently grew on the surface of something that is no longer there.

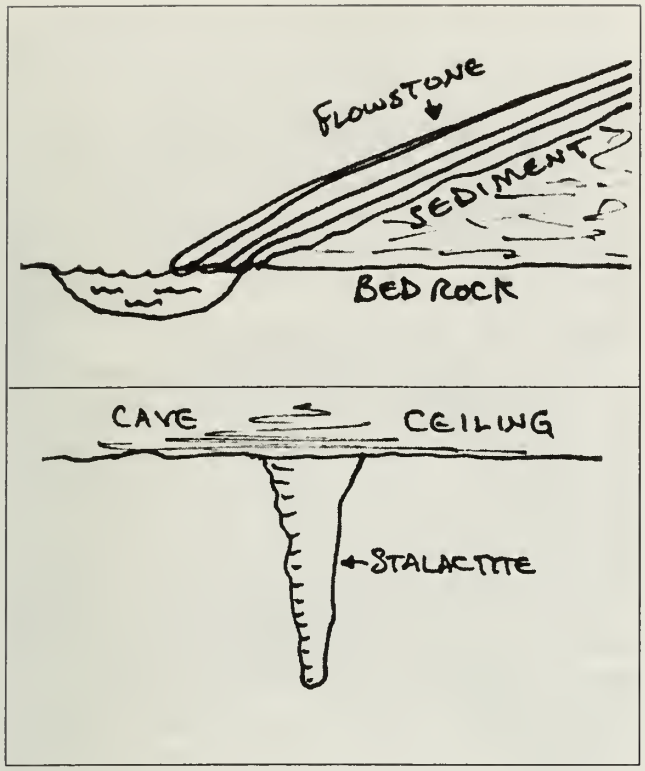
Clues:

1) Examine other flowstone in the cave and in other photographs. How does flowstone form and where is it normally found? (Hint: Refer back to Information Section on Speleothems).

2) Examine and compare flowstone that formed on a slope with a speleothem that formed from dripping water. Describe how their shapes are different and/or draw pictures.

Question 2:
If the mushrooms grew out on top of some material or liquid that is no longer there or that is now at a lower elevation, then what could have been there and now is gone or is now at a lower elevation in the cave?

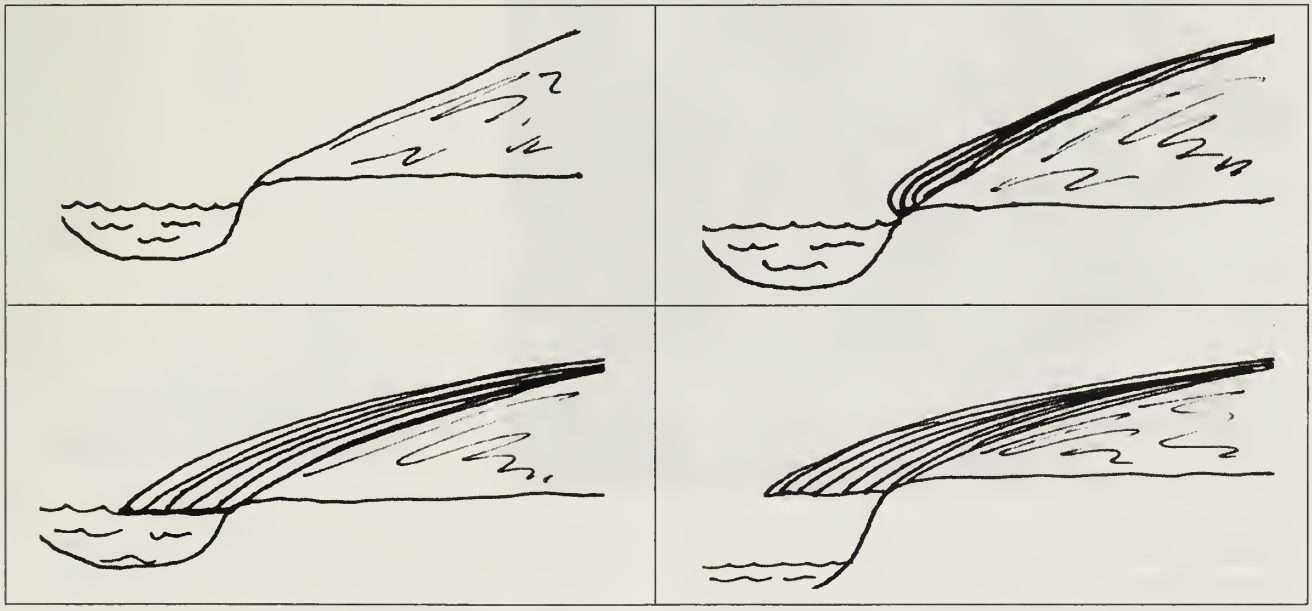
A: The mushrooms could have grown on top of sediment in the cave that was later eroded away, or they could have grown out over the cave stream when it was at a higher level.



Question 3:
If the mushrooms grew on the top of the stream, then why is the stream much lower in elevation today?

A: A wetter climate in the past could have raised the water level to the point where water was at higher level for long enough period to form the mushrooms. Another possibility is that the cave stream cut down into the cave floor and slowly lowered the stream level.

Answer: Draw four pictures that show the succession of events in growing a "mushroom". The pictures should show 1) the mud slope, 2) the formation of flowstone on top of the slope, 3) the mushroom growing out over the cave stream when the water level was higher, and 4) the mushroom as it looks today.



Mystery 7: Capitol Dome

Objectives

To learn that the appearance of geological features is not the result of a single event, but a sequence of events.

To learn to project geological processes into the future and predict eventual outcomes.

Background

Geologists work backwards using present-day observations to determine what happened in the past. This thought process uses the Principle of Uniformitarianism. Capitol Dome presents a unique opportunity to demonstrate how this thought process works (Figures 26 and 42).

Capitol Dome is a column that sits on an elevated area of the cave called a breakdown pile with a stream flowing around its base. Capitol Dome was formed by a succession of geologic events and processes that occurred at different times.

Examining the area around Capital Dome provides clues to the first of the events that resulted in the feature we see today. Notice that Capital Dome sits on an elevated area above the cave stream and that the cave ceiling above it is somewhat dome-shaped. The flanks of the elevated area show many blocks of limestone that probably fell from the ceiling creating a breakdown pile. The shape of the ceiling further supports the hypothesis that the blocks fell from the ceiling at some earlier time. As you walk up the side of the elevated area, notice that the steps you are using are actually blocks of sediment-covered rock that have fallen from the ceiling.

Originally, the cave stream flowed through the area where the breakdown pile now sits. As the stream eroded the walls and widened the cave opening, the limestone beds that formed the ceiling became increasingly unstable. When the flat ceiling could no longer support itself, blocks of limestone fell creating a more stable dome shape. The breakdown pile fell in the middle of the stream causing the stream to change course. Sediment from the stream and flood events filled in the empty spaces helping to stabilize the breakdown pile. Stalactites and stalagmites began to grow from the ceiling above, and on the breakdown pile below, eventually growing together to form a column. The column has continued to grow and widen to form Capital Dome (Figure 43).

During the evolution of Capital Dome, groundwater saturated with calcite flowed down the

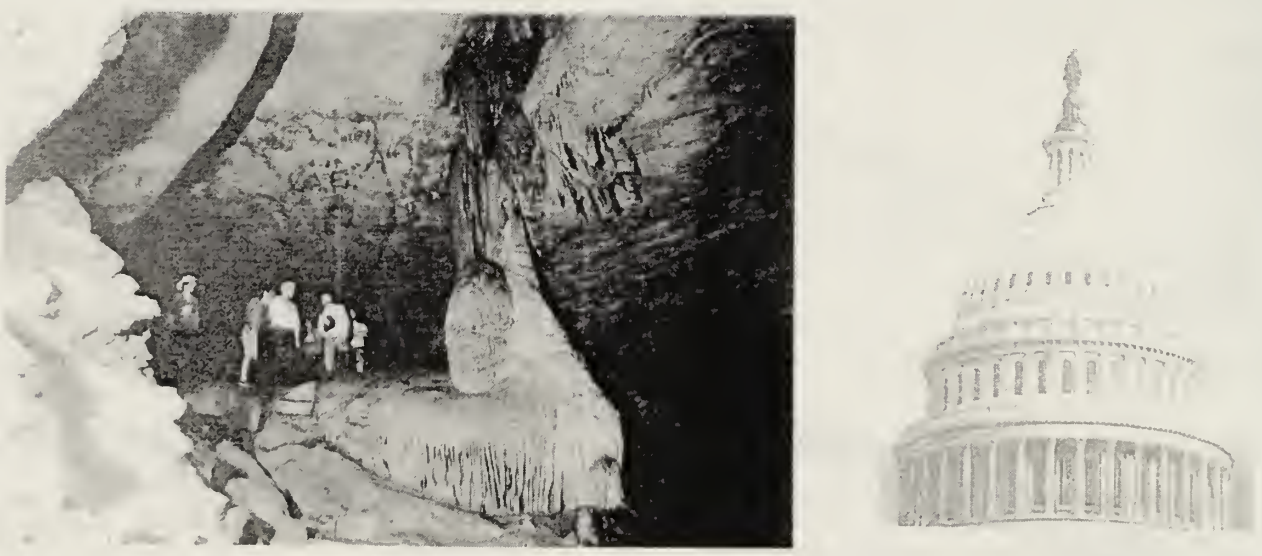


Figure 42. *The similarities between the U.S. Capitol Dome and Illinois Cavern's Capitol Dome are apparent in these two photographs.*

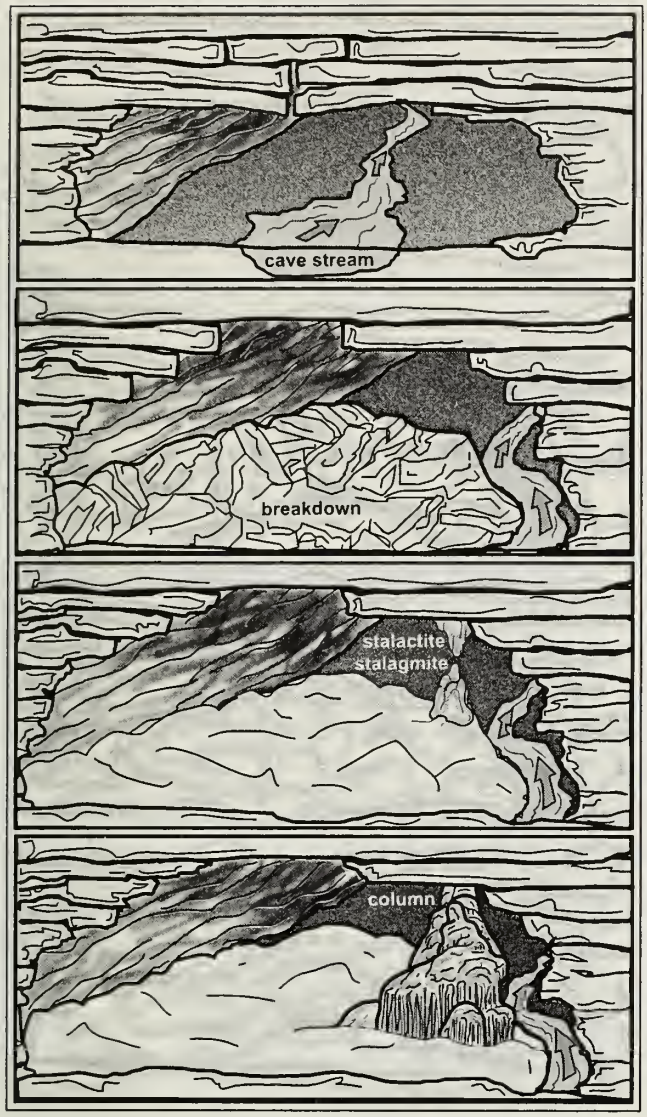


Figure 43. *Initially, the area now occupied by Capitol Dome was a relatively wide stream passage whose roof collapsed and formed a breakdown pile. Subsequent flooding deposited fine-grained sediment on the pile. Stalactites and stalagmites began to form above and on the pile, perhaps as a result of the collapse and the opening of pathways for soil water to enter the cave ceiling. One stalactite and stalagmite eventually grew together and continued to grow over the edge of the breakdown pile to form flowstone that now resembles the Federal Capitol Dome.*

front of the column and down the side of the breakdown pile. The continued growth of the original column resulted in the addition of flowstone on the front (facing the viewer). The column widened at the base and created a dome-shaped feature with subsidiary stalactites. The additional stalactites formed of exceptionally white calcite that makes the feature resemble the Capitol Dome in Washington, DC. The wetness of Capitol Dome suggests that it is continually bathed in groundwater and continues to grow at a very slow rate.

A present day example of how Capital Dome formed can be observed at this location. You will notice a large stalagmite behind Capitol Dome with water continually splashing on its surface (Figure 44). The water developing the stalagmite originates in the overlying soil zone and bedrock. The carbon dioxide-charged soil water is acidic and dissolves the limestone bedrock it encounters. Degassing of carbon dioxide, as the water enters the ceiling of the cave, causes the precipitation of calcite and the formation of the stalactites. The splashing of the water on the stalagmite causes accelerated degassing that results in a relatively rapid precipitation of calcite and formation of the stalagmite. The texture of the surface is covered by "microterracettes"; these are centimeter-size, cup-shaped depressions that hold small volumes, 1 to 2 milliliters, of water. These features are a clue that stalagmites and flowstone formed rapidly.

The flowstone on the front of Capital Dome is made of very pure calcite, which gives the feature its bright white appearance. The calcite of Capital Dome lacks impurities that add color to other developing cave features. Organic acids generated in soil and dissolved metals, like manganese and iron can color flowstone (and other cave formations) various shades of brown to black. In addition, fine sediment from flooding can accumulate on cave formations and become trapped within the growing features, also adding color to the feature. The absence of color in Capital Dome suggests that contemporary floodwaters rarely, if ever, reach the white part of the feature.

Suggested Discussion Questions

1) What features on Capitol Dome make it look like its namesake?

2) What processes, in order of occurrence, are

responsible for the formation of Capitol Dome and the mound it sits on?

3) What feature on top of the mound provides clues to the formation of Capitol Dome?

4) Where does the water come from that created Capitol Dome?

5) Is Capitol Dome still growing today? Hint: Is it wet or dry?

6) Why is the front part of the Capitol Dome so light in color?

7) What can you infer about the chemistry of the water splashing on the large stalagmite just behind Capitol Dome? Is the water saturated or undersaturated with the mineral calcite? What effect does the splashing have on the precipitation of calcite?

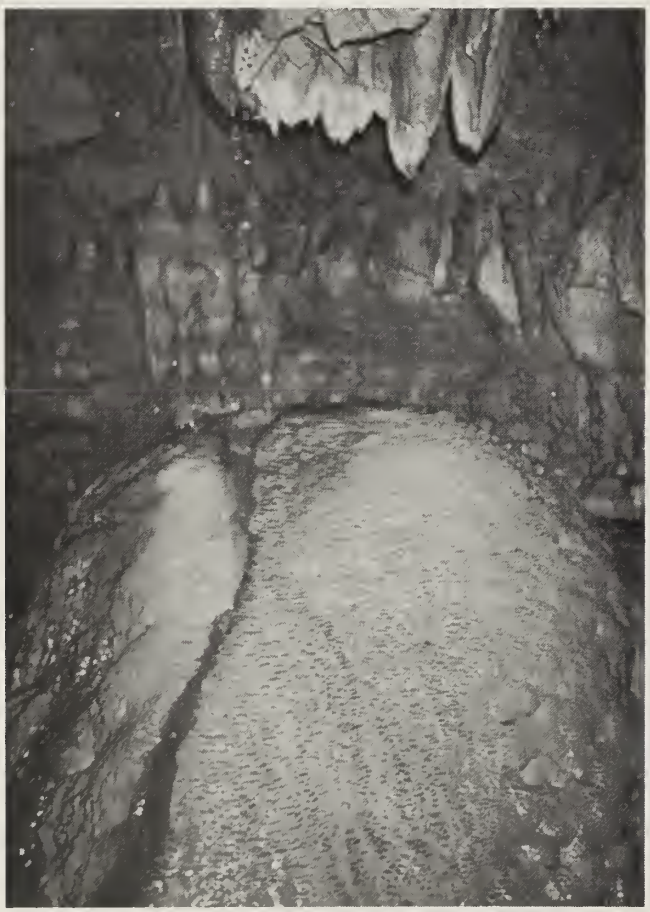


Figure 44. *A ceiling seep, charged with carbon dioxide and saturated with calcite, drips from small stalactites onto a large stalagmite located just behind Capitol Dome. This feature appears to be a precursor to another speleothem that will look similar to Capitol Dome.*

8) What will eventually happen to the large stalagmite and the stalactites behind Capitol Dome? That is, assuming they continues to grow, what type of speleothem will they become when the stalactites meet the stalagmite, and what does that tell you about the origin of Capitol Dome?

Answer Sheet

Suggested Discussion Questions

1) What features on Capitol Dome make it look like its namesake?

A: The general shape of Capitol Dome and the white stalactites on its front (reminiscent of white columns) make it resemble the US Capitol Dome in Washington, DC.

2) What processes, in order of occurrence, arere-sponsible for the formation of Capitol Dome and the mound it sits on?

A: 1) The collapse of the ceiling forming a breakdown mound; 2) flooding that deposited fine sediments (mud) within and on top of the breakdown; 3) formation of stalactites and a large stalagmite on top of the mound; 4) the stalactites and stalagmite grow together to form Capitol Dome.

3) What feature on top of the mound provides clues to the formation of Capitol Dome?

A: The large stalagmite behind Capitol Dome and the small stalactites above it are the precursors of another formation that will look very similar to Capitol Dome.

4) Where does the water come from that created Capitol Dome?

A: Water from rainfall and snowmelt seeps through the soil and into bedrock fractures overlying Capitol Dome. The water then winds its way through near-vertical and horizontal fractures probably for weeks or longer prior to entering the cave through the ceiling.

5) Is Capitol Dome still growing today? Hint: Is it wet or dry?

A: Capitol Dome glistens in the light because of a film of water on its surface. The presence of water indicates that it is still growing.

6) Why is the front part of the Capitol Dome so light in color?

A: The white stalactites and flowstone that make up the front of Capitol Dome are made of relatively pure calcite with little staining from organic content or sediment.

7) What can you infer about the chemistry of the water splashing on the large stalagmite just behind Capitol Dome? Is the water saturated or undersaturated with the mineral calcite? What effect does the splashing have on the precipitation of calcite?

A: The water dripping on the stalagmite behind Capitol Dome is saturated with the mineral calcite. The splashing accelerates the loss of carbon dioxide resulting in deposition of the mineral calcite.

8) What will eventually happen to the large stalagmite and the stalactites behind Capitol Dome? That is, assuming they continue to grow, what type of speleothem will they become when the stalactites meet the stalagmite, and what does that tell you about the origin of Capitol Dome?

A: The stalagmite and stalactites will join to form a column with a shape similar to that of Capitol Dome. The stalagmite and its stalactites provide an example of an early stage in the development of Capitol Dome.

Capitol Dome: Student Activity

The Setting

Capitol Dome is one of the highlights of Illinois Caverns. It is a spectacular speleothem that sits on a mound high above the cave floor and resembles its namesake.

The Mystery

What type of speleothem is Capitol Dome and how did it and the mound on which it sits form?

Procedure

Work through this mystery in groups and with the assistance of your teacher, and answer the following questions:

Question 1:
What material makes up the mound that the Capitol Dome speleothem form on?

Clues:

1)There are several types of material that make large piles or mounds in caves. They are:

a) fine-grained sediments (mud carried in by the cave stream)
b) breakdown (large rock slabs that fell from the ceiling)
c) flowstone (minerals precipitated from inflowing groundwater)

2) As you climb to the top and on the top of the mound on which Capitol Dome rests, examine the material that makes up the mound.

3) The mound could be made up of more than one of the three materials described above.

Question 2:

What type of speleothem is Capitol Dome?

Clues:

1)Examine Capitol Dome and determine what type of speleothem it most looks like. Your choices are: 1) Stalactite, 2) Stalagmite, 3) Column, or 4) Flowstone.

2) There is a large stalagmite with small stalactites above it growing just behind Capitol Dome. Examine these speleothems and draw what they look like now and what you think the stalagmite and its stalactites will look like when they grow together. As you draw, consider the possibility that these speleothems could grow into another Capitol Dome.

Draw four pictures to show the sequence of events that created the mound and Capitol Dome, starting with 1) an open cave passage with a flowing stream, 2) the formation of a mound, 3) the early development of Capitol Dome, and 4) Capitol Dome and its mound appear today.

Answer Sheet

Question 1:

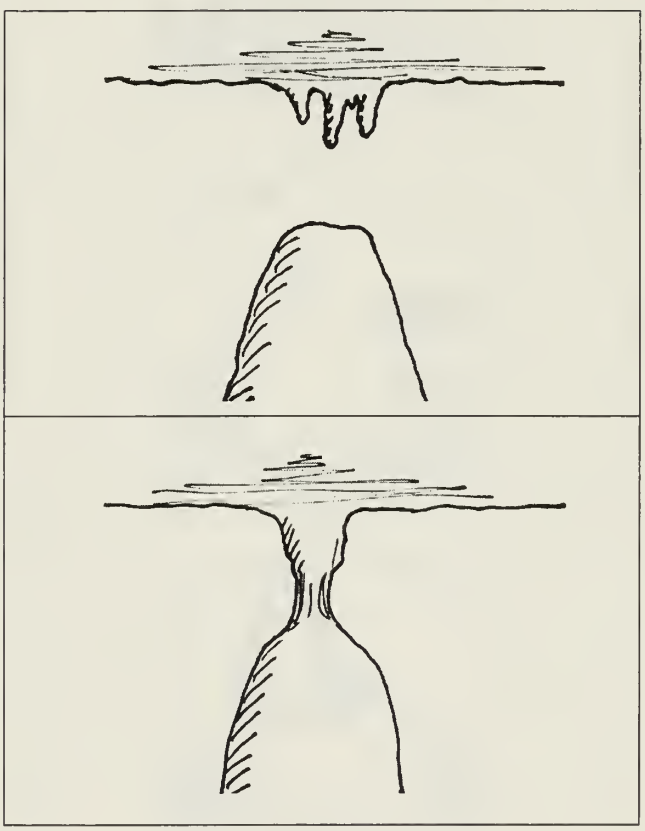
What material makes up the mound that the Capitol Dome speleothem formed on?

A: The mound on which Capitol Dome rests is made up of breakdown that formed when the ceiling collapsed and formed a breakdown pile. Fine-grained sediments, carried into the cave by the cave stream during flood events, were deposited on top of and within the pile. As you climb the mound, you are using breakdown blocks, previously covered with sediment (worn down by visitors), as steps. Finally, the ceiling seeps began depositing speleothems in the form of flowstone and stalagmites on top of the mound. The answer is that the mound is made up of all three types of materials.

Question 2:

What type of speleothem is Capitol Dome?

A: Capitol Dome is a column. At some point in its evolution it was a cluster of small stalactites over a large stalagmite. The stalactites and stalagmite eventually joined to form Capitol Dome. The large stalagmite behind this feature is probably what Capitol Dome looked like prior to connecting with the overhanging stalactites.

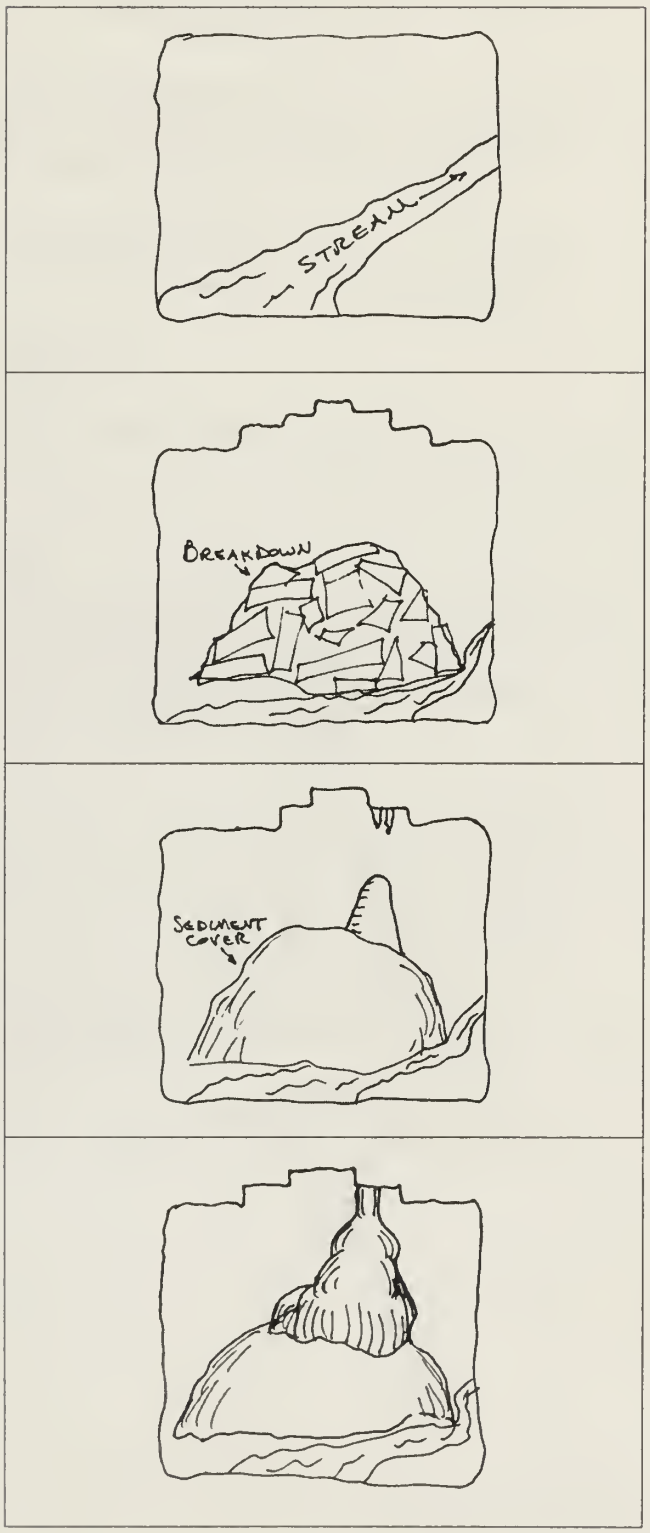


Clues:

1)Examine Capitol Dome and determine what type of speleothem it most looks like. Your choices are: 1) Stalactite, 2) Stalagmite, 3) Column, or 4) Flowstone.

2) There is a large stalagmite with small stalactites above it growing just behind Capitol Dome. Examine these speleothems and draw what they look like now and what you think the stalagmite and its stalactites will look like when they grow together. As you draw, consider the possibility that these speleothems could grow into another Capitol Dome.

Answer: Draw four pictures to show the sequence of events that created the mound and Capitol Dome, starting with 1) an open cave passage with a flowing stream, 2) the formation of a mound, 3) the early development of Capitol Dome, and 4) Capitol Dome and its mound appear today.



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